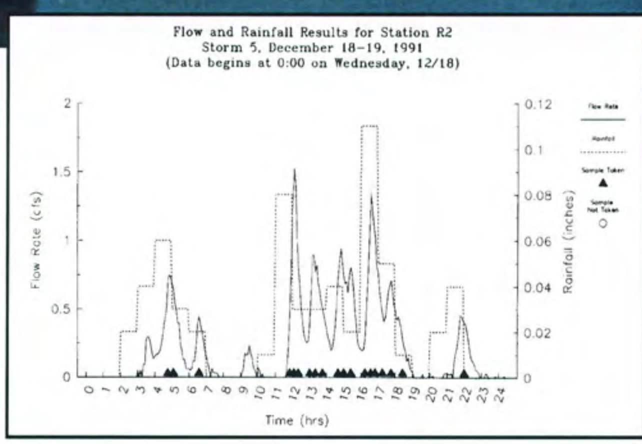
FINAL REPORT

ANALYSIS OF OREGON URBAN RUNOFF WATER QUALITY MONITORING DATA COLLECTED FROM 1990 TO 1996



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This report provides a summary of an Oregon Association of Clean Water Agencies (ACWA) sponsored project to evaluate the data collected from land use based stormwater monitoring conducted in Oregon. The larger municipalities and the Oregon Department of Transportation (ODOT) were required by the Clean Water Act Amendments of 1987 to prepare a comprehensive application for and then to comply with a National Pollutant Discharge Elimination System (NPDES) permit for discharges from the municipally owned and operated separate stormwater systems. Under both the application and permit requirements, the permittees conducted comprehensive land use runoff monitoring programs which required significant effort and resources. The purpose of this project was to evaluate from a statewide perspective what has been learned from this stormwater monitoring effort and to evaluate the usefulness of continued monitoring which focuses almost exclusively on characterizing runoff quality from different land uses. In addition, an estimate of typical monitoring costs for land use based stormwater monitoring was developed and a list of other potentially useful monitoring activities (other than land use monitoring) was compiled.

Urban land use runoff water quality data were collected by a number of agencies in Oregon including Clackamas County, the City of Eugene, the City of Gresham, the Oregon Department of Transportation, the City of Portland, the City of Salem, and the Unified Sewerage Agency primarily to meet municipal stormwater NPDES Permit Application and Permit Requirements. Several of these agencies collected data in excess of the minimum requirements in order to provide a more comprehensive data set and/or to develop information useful for watershed planning and assessment efforts. The data were collected between 1991 and 1996. This data was obtained from the agencies and compiled into a database. The main tasks of this project were to compile these data from the agencies, develop a database of Oregon urban stormwater runoff data and then to perform and document an analysis of the data.

The primary focus of the data analysis was to assess what has been learned about stormwater runoff in Oregon with respect to land use based chemical monitoring. The analytical approach to meet this objective was as follows: first, stormwater concentration data from stations with similar land uses were statistically compared with each other to determine if they could be combined together to characterize runoff from a specific land use; second, statistical analyses were performed on the combined data to assess whether different land uses statistically appeared to have different concentrations. Combining data from similar land use monitoring stations for all of the agencies was done to provide a greater understanding of the quality of runoff in Oregon and increase the statistical confidence in the conclusions drawn from comparisons.

In addition to the efforts to characterize different land use runoff, this document provides information on pollutant concentrations measured at each monitoring station. Concentrations of dissolved metals and other conventional pollutants at each station are compared with Oregon and Federal water quality standards to provide an indication of the potential for runoff to cause an impairment of aquatic habitat and human health. The runoff data from stations were also compared with data collected under the National Urban Runoff Program (NURP) (EPA, 1983), the Federal Highway Administration (FHWA) (Driscoll et. al., 1990), and the San Francisco Bay area programs (Woodward-Clyde, 1996) to provide a better understanding of the nature of Oregon's stormwater runoff water quality as compared to national and west coast values.

Section 2 of this report presents a brief overview of the database developed for the project, Section 3 describes the land use statistical analyses performed and results, Section 4 presents the results of the comparative analyses, Section 5 discusses the adequacy of the current data, Section 6 describes typical monitoring costs, Section 7 lists other monitoring options, Section 8 presents the summary and conclusions of the study, and Section 9 lists the references cited.

2.1 GENERAL

The permittees represented in the ACWA stormwater committee have collected a significant amount of urban municipal separate storm systems (MS4) stormwater quality data which has served them individually to comply with their NPDES MS4 permits. The ACWA committee has taken a cooperative approach to combine and share stormwater data in an effort to provide effective direction to future municipal stormwater monitoring efforts in Oregon. To provide an easy method for storing, retrieving, and analyzing the permittees stormwater quality data, the ACWA committee initiated this project to develop an Oregon stormwater relational database. This section describes the contents and structure of the ACWA stormwater relational database, and it provides a description of how the database was used to perform the data analysis presented in Section 3.0.

2.2 DATABASE CONTENTS

Included in the ACWA database are the analytical results from NPDES stormwater monitoring conducted by Clackamas County, the Oregon Department of Transportation (ODOT), the Unified Sewerage Agency (USA), and the cities of Eugene, Gresham, Portland, and Salem. The primary focus of the data compilation was on wet weather water quality data collected as flow-weighted composite samples. These data included measurements of heavy metals, sediments, and nutrients. Grab sample storm event data were also compiled in the database to include parameters for bacteria, and oil and grease. In addition to the storm event water quality data, dry weather (base flow conditions) sampling data was included for agencies that provided this information. Results for organic parameters were excluded from the database because they were generally not detected in significant amounts to perform statistical analysis.

Other important information that was included in the database was monitoring station characteristics and storm event hydrologic data. Descriptions of the monitoring station characteristics for the seven agencies' sampling programs are provided in Tables 2-1a through 2-1d. Stations in these tables are grouped by their predominant land use characteristic, which is either residential, commercial, industrial, mixed (variety of land uses), open space, or transportation. As shown in Tables 2-1a through 2-1d, the sampling programs conducted by the agencies differ in the number of stations monitored, the number of storm events monitored and the types of land uses monitored. In total, the database includes information from 39 monitoring stations and with up to 15 sampling events at a station, and almost 320 monitoring data points.

2.2.1 Data Quality Control

Differences in sampling methods may affect data quality and/or comparisons between data sets. As an example, the ODOT, USA, and the cities of Portland, Eugene, Salem, Gresham all collected flow-weighted composite samples using automated samplers. These agencies attempted to sample at least 75 percent of the storm event. To achieve this some agencies used telemetry systems to monitor sampler progress and, as necessary, they performed bottle replacement. Other agencies did not incorporate telemetry in their monitoring systems, and therefore, the need for bottle replacement could not be ascertained during instances when the actual runoff volumes exceeded the predicted volumes. At times this resulted in sampling less than 75 percent of the storm event. Clackamas County did not use automated samplers but instead manually collected samples and flow measurements on timed intervals for the first three hours of the storm event. The series of collected samples were proportioned based on flow and composited. In effect, this resulted in a 3-hour flow-weighted composite sample. To allow for consideration of these differences in sampling methods, applicable sampling method information (e.g., grab, flow-weighted composite, 3-hour composite) and the percent of the storm event monitored was provided for each database record.

A thorough quality assurance and quality control (QA/QC) review of all of the data was not performed as part of this project. The data provided by the agencies for incorporation in the database was generally data that had already been summarized and reported to the Oregon Department of Environmental Quality (DEQ) and, therefore, it was assumed that this data met U.S. Environmental Protection Agency (EPA) guidelines for quality control. However, there was some uncertainty as to how the different agencies treated results that were questionable due to laboratory QA/QC measures. In some instances, agencies used EPA estimation procedures to correct the questionable result and in other instances the questionable result was not adjusted. To ensure that these effects could be considered when analyzing the data, a QA/QC rating number for the data was implemented. Analytic results that were not estimated and for which there was no indication that the result was questionable were given a rating number of 3; for results that were estimated based on a QA/QC review were given a rating number of 2; for results that were not estimated but for which there was evidence that the result was questionable were given a rating number of 1. This information is contained in the database.

2.3 DATABASE STRUCTURE

The ACWA database was developed in Microsoft Access and is organized into four tables: AnalyteRef, Chemical, StormData, and Location. A description of each table is provided below.

- AnalyteRef - This table provides a listing of analyte names, their common pseudonym, and the units of measure associated with the analyte. This table contains 71 records, and serves as a reference source on how an analyte is named in the database.
- Chemical - This is the primary data table for analytical results. It contains more than 14,000 records and each record is specific to one analytical result. Each record consists of the following information:

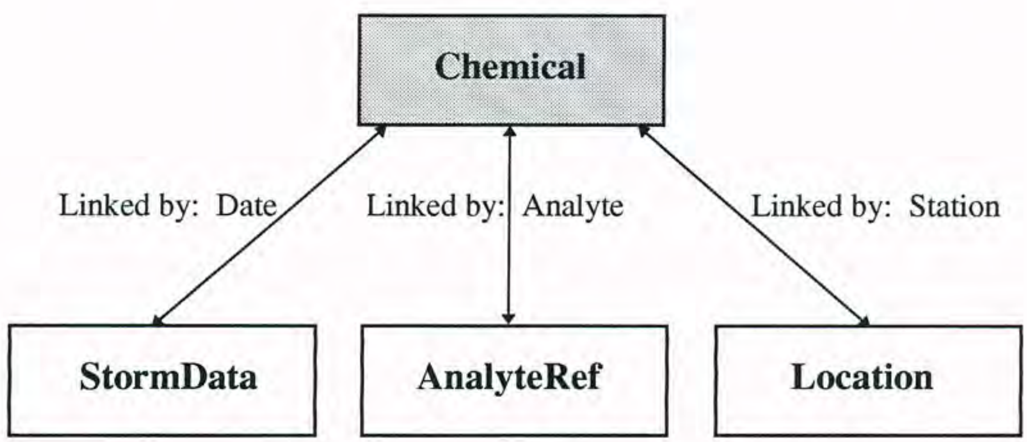
Agency -	name of agency that collected the data
Station -	name of station, as referred to by the agency
Date -	month, day, and year of sampling event
Analyte -	name of analyte that was analyzed
Results -	results from laboratory analysis (left blank for non-detect)

Detection -	indicator of non-detect results (enter ND)
Detection Limit -	detection limit for the analysis method used
Units -	units of results
Method -	standard lab method used for analyte testing
QA/QC -	a rating number evaluating the sampling programs quality assurance and quality control process
Comments -	specific information on the sample or sampling event
Sample Type -	whether the sample is a grab or a flow-weighted composite

- Location - This table provides information on each station's location, drainage area, land use classification, percent land use distribution, conveyance configuration (piped or open channel), receiving water body, and average daily traffic (ADT). It is related to the Chemical table by the station name and the agency that monitors the station.
- StormData - This table provides descriptive information on each sampling event conducted. Specific information includes the date of the sampling event, the type of sampling conditions (wet, dry or ambient), the volume of rainfall for the storm event, the duration of the sampling event, the percent of the storm event sampled, the antecedent dry period prior to sampling, and the laboratory that performed the analytical analysis. This table is related to the Chemical table by the date of sample collection.

Figure 2-1 illustrates the relationship structure of the four database tables. The Chemical table is linked to the other three tables by a key data field which is listed in Figure 2-1 next to each connecting arrow.

Figure 2-1 ACWA Stormwater Database Table Relationships



2.4 USING THE ACWA STORMWATER DATABASE

Specific data from each individual table can be extracted and analyzed by constructing and running a query or a query can be constructed to obtain desired sections of data from a combination of tables. For example, a query could be built to find and list all of the TSS data for the City of Eugene's residential stations collected during the first three storm events. This query would relate and pull information from the Chemical, Location and StormData tables. There are two queries that have been constructed as part of the database: "HardnessDep" and "NonHardnessDep." These two queries are designed to list and compare analytes to federal and state water quality criteria. For analytes whose criteria is a function of hardness, the "HardnessDep" query first finds from the Chemical table the hardness measured for the sample and then it calculates the criteria for comparison. If hardness data is not available, a conservative value of 25 mg/L is used.

In addition to comparing water quality results to state and federal standards, this project performed several statistical analyses that are explained in Section 3.0. The database was used to expedite this analysis process by providing a means for organizing specific sets of data. Queries were developed as needed and run on the database to extract data so that it could be exported in the correct format to another software program for statistical analysis.

3.1 SUMMARY STATISTICS FOR INDIVIDUAL STATIONS

In this study, statistical analyses for evaluating runoff from individual stations and different land uses were performed using event mean concentrations (EMC) of each of the pollutants analyzed. EMC is defined as the average pollutant concentration of the total volume of runoff from a storm event. The data reported for most of the stations in this study were based on flow-weighted composite sampling where an attempt was made to collect water samples over the entire storm event. Thus, these flow-weighted samples provide the estimate of EMCs directly. Exceptions are the data from Clackamas County monitoring stations. The stormwater samples from Clackamas County were collected as flow-weighted composites over the first three hours of each storm instead of the entire storm duration. As a result, the concentration of constituents analyzed as flow-weighted composites at these stations represented averages over the first three hours of each storm.

When multiple storm events are monitored at a given location, the EMCs observed are usually quite variable (EPA, 1983; Driscoll et. al.,1990). Parametric statistical tests assume that the data being analyzed are normally distributed. In order to meet this assumption when data are not normally distributed, they are often "transformed" so that the transformed data are normally distributed. It is generally accepted that due to its high variability, stormwater quality data are usually well characterized by a lognormal probability distribution (EPA,1983; Driscoll et. al.,1990). Therefore, stormwater data are often log-transformed to a normal distribution for statistical characterization and analyses. For each station, an assessment was made for each of the following pollutants as to whether the data were well characterized by the lognormal distribution. Summary statistics were then prepared for each of the following parameters based upon the transformed data:

- Total Suspended Solids (TSS)
- 5-day Biochemical Oxygen Demand (BOD_5)
- Chemical Oxygen Demand (COD)
- Total and Dissolved Phosphorus (P)
- Total Kjeldahl Nitrogen (TKN)
- Nitrite and Nitrate (NO_3+NO_2)
- Total and Dissolved Copper (Cu)
- Total and Dissolved Lead (Pb)
- Total and Dissolved Zinc (Zn)

For each station and each pollutant EMC listed above, lognormal probability plots and statistical results are presented in Appendix A. Stations with less than five data points for a particular constituent were excluded from the statistical summaries of individual stations for that constituent only. With less than 5 data points, it was felt that the statistics calculated would have too much uncertainty. These situations are indicated in Appendix A.

The acceptability of the use of the lognormal distribution was judged by how well the plotted points corresponded with the theoretical distribution (straight line). A visual review of the probability plots indicates that, in general, the stormwater data in Oregon are well described by the lognormal distribution. Figure 3-1 presents example probability plots from 4 stations. The Probability Correlation Coefficient (PPCC) (Vogel, 1986) tabulated in the statistical summaries listed below the probability plots in Appendix A indicate how well the data points correspond with the theoretical distribution. A value of PPCC = 1 represents a perfect match. A low PPCC (less than .90) indicates that the lognormal distribution may not adequately describe the data. The values of the PPCCs for the individual stations in the ACWA data set are usually in the range of about 0.91 to 0.98, indicating the general acceptance of lognormality. Therefore, the lognormal distribution was used to develop statistical summaries of the data.

The statistical summary of pollutant discharges for each station includes the mean, standard deviation, coefficient of variation, percentile distribution (median, 10^{th}, 25^{th}, 75^{th}, and 90^{th} percentiles) and 90 percent confidence intervals on the median (50^{th} percentile). Also included in the summary are the number of samples and percentage of non-detects in the samples. The results are shown in Appendix A. The statistical parameters listed in the summary are computed from the EMCs assuming they follow a lognormal probability distribution.

Data below the detection limits (i.e., sample results reported as "non-detects" or "ND") are typically a result of the limitations of the laboratory analytical methods to quantify pollutant concentrations at low (trace) levels. They can also be influenced by both laboratory and field QA/QC analyses that indicate that there was likely some contamination of the sample. Non-detects (NDs) have an effect on statistical parameters when they exist in a data set. Traditional practices for dealing with NDs have differed and have led to biases in estimation of parameter statistics (Driscoll et.al., 1990). The statistical characterization method employed in this study utilizes the NDs when rank ordering the data points for determining the probability (frequency) but only includes the subset data points above the analytical method's detection limit together with their ranking when determining statistical parameters mentioned above. Details regarding this method can be found in Driscoll et. al., 1990. The exception to this treatment of NDs occurred when the ND was above more than 2 reported values. In this case the ND was dropped from the analysis.

3.2 EVALUATION OF POOLING DATA FROM SIMILAR LAND USE STATIONS

Methodology

The next step in the land use characterization analysis was to determine if data from similar land use stations could be combined to: 1) improve the estimates of land use based concentrations;

and 2) improve the power of statistical tests for determining whether different land uses have different concentrations. The method included statistically evaluating whether one could reject the hypothesis that the data from different stations is in fact different. Because of resource limitations, this analysis was performed on a selected sub-set of parameters which included: TSS, total phosphorus, total Cu, dissolved Cu and total Zn. These parameters were chosen to represent the nutrients and metals that are typically of concern. In addition, TSS is often used as an indicator of other pollutants because of the tendency of many pollutants to attach to fine particulates.

An important assumption made in this analysis was that the contaminant concentrations measured at each station are strongly influenced (dominated) by the land use found in the station's drainage area. If other factors (such as geology, meteorology or non-land use specific activities) are the dominant factors which influence pollutant concentrations in runoff then this analysis would not produce results that show similar land use stations as being similar in constituent concentrations.

The concentration data from all stations were divided into the following six groups:

- commercial
- residential
- industrial
- transportation
- open space
- mixed land use stations

The data of chosen parameters for each station land use type were then evaluated to determine if the station data for a given land use were statistically comparable and could be combined ("pooled"). Mixed land use stations were excluded from the statistical analysis for land use comparisons. Mixed land use stations do not display consistent characteristics (e.g., USA Station UM1 contained 5% industrial land use as compared to the City of Gresham station E-3 which contained 52% industrial land use). Appendix B contains box plots showing the medians and 95 percent confidence interval of the median for each individual similar land use station for TSS, total phosphorus, total Cu, dissolved Cu, and total Zn. Also shown are the results of an all pairs Tukey-Kramer HSD (honestly significant difference) test for the mean and a Levene test for the variance (Berthouex, 1994). These tests were used to evaluate whether or not to reject the hypothesis that the station data are different. Stations which failed statistical tests for mean and variance (that is the hypothesis that they were different could not be rejected) were considered for exclusion from the combined data as statistically different from the group. However, statistical testing was not (and should not be) the only criterion in the station screening. When stations are excluded from a group based upon statistical differences, their characteristics should be reviewed to determine what might be causing them to be different (e.g., downstream end of a treatment system, instream vs. pipe, or other distinct characteristics). These characteristics were evaluated.

Results - Station Data Pooling Analysis

Based upon the results, data from several stations were excluded from the pooled data land use assessment. The stations were excluded based on following considered together:

1. Statistical testing results for mean and variance of several constituents showed that the data from the stations were not similar to other similar land use stations;
2. Stations with specific characteristics (distinct conveyance configuration, downstream of a wetland, etc.) that were different from other similar land use stations; and
3. Stations which did not have a minimum of five useable data points for a parameter.

Excluded stations and the reason for the exclusions are listed in Table 3-1. For the remaining stations, the data are provided in box and diamond plots in Appendix B. Figures 3-2 and 3-3 provide examples of the box and diamond plots for TSS at the commercial stations and for total Cu at the industrial stations.

Table 3-1. Stations That Were Excluded from the Pooled Data Land Use Analysis

Land Use	Excluded Stations	TSS	Cu	Zn	Dis -Cu	Reason for the Exclusion
Resi.	Portland:R-1	✔	✔	✔	✔	Only instream station in the residential station group; statistically different from others.
Comm.	USA: UC1b	✔	✔	✔	✔	Behaved statistically different from others; site was in a relatively unbusy shopping site as compared to other sites; means were low.
	USA: UC3	✔				Experienced sediment deposition problem.
	USA: UC2		✔			Mean for total Cu was statistically different from the grouped mean.
Indus.	Eugene: I-2	✔	✔	✔	✔	Located at the downstream end of a wetland.
Trans.	None					
Open	None					

When pooling station data, total phosphorus was initially included as one of the pollutants for evaluation. However, total phosphorus was dropped from the evaluation as concentrations were not found to be consistent among stations with similar land uses. For total phosphorus, concentrations may be more affected by soil types than by land use.

When evaluating data from similar land uses, it was found that data from instream stations and piped stations were statistically different from one another. Therefore, stations from industrial land uses were sub-divided into instream and in-pipe industrial stations according to their different conveyance system configurations. This was not done for residential, commercial and transportation land uses because commercial and transportation stations are all in-pipe stations, and there is only one instream station for residential land use (Fanno Creek in Portland) and this station was dropped from the land use analysis.

Based upon the results of these tests, data were then pooled for testing of differences between land use types as described in the following section.

3.3 POOLED LAND USE DATA ANALYSIS

After the individual storm event concentrations were pooled for each land use type, a statistical analysis similar to the one for individual stations was conducted for the combined data. An inspection of the information based on the grouped data indicate that:

1. The assumption of the lognormal distributions for the combined data appears to be valid and is, generally, improved;
2. The degree of variance in summary statistics (measured by the coefficient of variation) is reduced.

The assessment of whether land uses were different from each other in storm EMCs was performed using the Student's t test. The Student's t test is a means comparison method to check if the actual difference in the two means is greater than the difference that would be considered to be significant. The hypothesis is that the stations are similar and when rejected, one could assume that they are in fact different. Figures 3-4 to 3-7 show the land use pooled distribution box and diamond plots for TSS, total Cu, total Zn, and dissolved Cu respectively. When the 90% confidence bands do not overlap between two land uses, this indicates that the two land uses are statistically different from one another.

Comparison of Pollutant Concentrations from Various Land Uses

The data contained in the ACWA database were used to compare land use specific concentrations of TSS, total Cu, dissolved Cu, and total Zn. The estimates were made using the statistical methods described. Mixed land use data were not included in this comparison, as the data from mixed stations represents runoff from a combination of various land uses.

To further evaluate the difference that the conveyance system type (piped or open channel) might have on pollutant concentrations in stormwater, a separate analysis was conducted on the mixed land use stations. This was done because of the limited number of other land use stations which were open channels. The mixed land use concentration data were divided into two groups, data collected from in-pipe stations and data collected from instream stations. Similar statistical analyses were employed to conduct the comparison between the two groups and results are discussed below and shown in Appendix B.

Table 3-2 shows the mean concentrations for each land use category. Total phosphorus is presented for comparative purposes only. A generalized summary of relationships between different land uses were developed and are identified in Table 3-3. Box and diamond plots which illustrate the mean comparisons are presented in Appendix B.

Table 3-2. Land Uses Mean Concentrations for Selected Pollutants

Land Use	TSS mg/l	Total Cu mg/l	Total Zn mg/l	Dissolved Cu mg/l	Total P mg/l
In-pipe Indus.	194	0.053	0.629	0.009	0.633
Instream Indus.	102	0.024	0.274	0.007	0.509
Transportation	169	0.035	0.236	0.008	0.376
Commercial	92	0.032	0.168	0.009	0.391
Residential	64	0.014	0.108	0.006	0.365
Open	58	0.004	0.025	0.004	0.166

Table 3-3. Land Uses That Were Determined to be Different from Each Other for the Selected Pollutants

Land Use	TSS	Total Cu	Total Zn	Dissolved Cu
In-pipe Indus.	Instream Indus. Commercial Residential Open	Instream Indus. Commercial Residential Open	Instream Indus. Transportation Commercial Residential Open	Open
Instream Indus.	*In-pipe Indus.* *Transportation* Open	*In-pipe Indus.* Residential Open	*In-pipe Indus.* Residential Open	Open
Transportation	Instream Indus. Commercial Residential Open	Residential Open	*In-pipe Indus.* Commercial Residential Open	Open
Commercial	*In-pipe Indus.* *Transportation* Residential Open	*In-pipe Indus.* Residential Open	*In-pipe Indus.* *Transportation* Residential Open	Open
Residential	*In-pipe Indus.* *Transportation* *Commercial*	*In-pipe Indus.* *Instream Indus.* *Transportation* *Commercial* Open	*In-pipe Indus.* *Instream Indus.* *Transportation* *Commercial* Open	
Open	*In-pipe Indus.* *Instream Indus.* *Transportation* *Commercial*	*In-pipe Indus.* *Instream Indus.* *Transportation* *Commercial* *Residential*	*In-pipe Indus.* *Instream Indus.* *Transportation* *Commercial* *Residential*	*In-pipe Indus.* *Instream Indus.* *Transportation* *Commercial*

Note: Italics indicates that means for that land use are larger than the land use category in the first column; otherwise the mean is smaller.

The results demonstrate that open space and in-pipe industrial stations generally have significantly different pollutant discharge levels (lower and higher, respectively) than the other land use stations. Open space showed consistently lower pollutant concentrations for all the parameters and is statistically different from most other land use types, except for residential stations (typically the next lowest), where the two land use types are not statistically different for TSS and dissolved Cu. Residential land use also showed lower pollutant concentrations than the other developed land uses, but was higher than open space. In-pipe industrial stations, on the other hand, represent the highest pollutant concentrations in all land use types. For most of the selected pollutants, in-pipe industrial concentrations were only statistically similar to the transportation land use concentrations.

Transportation and commercial land uses generally showed higher concentrations for all the pollutants than residential land use. They were statistically different from residential for TSS, total Cu and total Zn. Transportation and commercial land uses were different from each other for TSS and total Zn. They were not statistically different for total and dissolved Cu.

Residential stations were statistically different from other stations for total Cu and Zn. For TSS they were only significantly different from in-pipe industrial, transportation and commercial land uses. Residential pollutant concentrations were relatively low compared to other land use types, except for open space.

In terms of pollutants, total Zn illustrates the most variability for different land uses, followed by total Cu and TSS. Dissolved Cu exhibits the least variability for various land uses.

For this report, an assumption was made that if any land use type was significantly different from another land use for more than two parameters studied, it could be considered as significantly different from other land uses for the pollutant loadings in stormwater runoff. Table 3-4 shows the determined relationships for the six land use types.

The data from various stations for total phosphorous were highly variable when grouped by land use so they were dropped from the land use analysis. Station grouping by agency (all stations collected by an agency) was evaluated to determine the potential significance of regional differences (i.e., potentially related to soils). Figure 3-8 shows the results of grouping all station data from an agency together. The box and diamond plots and statistical summaries for total phosphorous by station can be found in Appendix B. Results indicate that stations from Gresham, Salem and Clackamas County show a high degree of conformance with each other, whereas stations from Portland, Eugene and USA (the relatively larger agencies and sampling areas) demonstrated a high variability among their stations. This could be a function of more consistent soil types in the smaller jurisdictions. The statistical analysis based on the groupings show that Portland and Eugene stations exhibited relatively high phosphorous concentrations and were not significantly different from each other. Gresham and Salem data were not significantly different from each other and the concentrations from these cities are the lowest compared to other agencies. USA and Clackamas stations were in the middle range and were not statistically different from each other. A useful analysis to substantiate that the soils types are the dominant determinant of phosphorus concentrations in urban runoff would be to evaluate the dominant soil types in each station catchment and conduct an analysis on soil type categories.

Table 3-4. Land Uses That Were Not Considered Different from Each Other

Land Use Type	Residential	Commercial	Instream Industrial	In-pipe Industrial	Transport-ation	Open Space
Residential						
Commercial						
Instream Industrial		✔				
In-pipe Industrial						
Transportation			✔	✔		
Open Space						

✔ = Land uses that were not considered to be different from each other

Note: Shading was used to block out redundant comparisons

In order to assess the potential severity of urban stormwater pollution in Oregon, the stormwater data collected in the ACWA database were evaluated with respect to the frequency which the observed concentrations exceeded the receiving water Oregon State Water Quality Standards for the protection of aquatic life. The data were also compared to national values and more recent data collected in the San Francisco Bay Area to gauge the levels of pollution observed in Oregon as compared to other areas. This analysis was completed by land use type.

4.1 COMPARISON OF POLLUTANT CONCENTRATIONS WITH WATER QUALITY STANDARDS

Dissolved metal concentrations and other conventional parameters (TSS, oil and grease) were compared to existing water quality objectives and standards to provide an indication of the potential for runoff to cause impairment of receiving water bodies. Water quality standards for Oregon's receiving waters are listed in Oregon Administration Rules, Chapter 340, Division 41, Section 445 (OAR 340-41-445). The water quality criteria are presented in Table 20 at the end of Division 41. Water quality standards and criteria are specified for the Willamette River Basin and the Columbia River. Only QA/QC qualified data in ACWA database have been used in comparisons to standards and criteria.

It should be pointed out that the water quality standards and criteria, which apply to instream pollutant concentrations after mixing of the stormwater runoff, represent concentrations of pollutants in the receiving water that are not to be exceeded in order to protect the specified beneficial uses. The stormwater quality data collected at instream stations represent instream pollutant concentrations which can be directly compared to the standards and criteria. The data collected at in-pipe stations, represent concentrations that do not reflect actual instream concentrations. To estimate the instream concentrations, one would need to use a detailed receiving water model that could account for not only the flow and pollutant data from the stations, but also upstream conditions. No attempt has been made here to perform this modeling effort. Therefore, the in-pipe stations are conservatively compared to the water quality criteria as a means of assessing potential impacts. Specific wet weather criteria and standards have not been developed by EPA or Oregon DEQ. However, the comparisons can be used to help target land uses for Best Management Practices (BMPs) when considered with the sensitivity of the actual receiving water.

When the heavy metal concentrations are compared to water quality criteria, it has been considered appropriate to compare these concentrations to acute criteria, as the storm events are episodic in nature. The acute criteria are not to be exceeded over a one hour period more often than once every three years on average.

The ACWA database information was compared to the standards for dissolved heavy metals, TSS, and Oil and Grease. No water quality standards or criteria have been set for TSS and oil and grease. However, benchmarks of 130 mg/l for TSS and 10 mg/l for oil and grease have been proposed by Oregon DEQ for industrial stormwater discharges (Draft NPDES 1200-Z General Permit for Storm Water Discharges). These "benchmarks" are used here for comparative purposes only.

Tables 4-1a and 4-1b list the percentage of times that a dissolved heavy metal was detected and the percentage of times it exceeded the hardness-based acute water quality criteria for receiving waters. The number of samples and percentage of detects at each station as well as summaries for specific land uses are also included in the tables. Table 4-2 provides a summary of exceedances for non-hardness dependent dissolved metals with the corresponding water quality criteria. Table 4-3 includes the comparisons for TSS and oil and grease.

For the dissolved metals that are not hardness dependent, none of the samples had concentrations of dissolved antimony, beryllium, iron, selenium or thallium higher than the dissolved water quality criteria. For the dissolved metals that are hardness dependent, no exceedances were found for dissolved chromium (Cr) and nickel (Ni). For exceedances that were identified, the frequency that the urban stormwater EMCs in the ACWA database were higher than receiving water acute standards were: Zinc (41%), Copper (30%), Cadmium (5%), Lead (1%), Silver (1%). If chronic criteria were evaluated, the number of exceedances would likely increase.

Dissolved Pb, and Ag rarely exceeded the acute water quality criteria, with only a few samples from the commercial, industrial and residential land use stations having concentrations higher than the criteria. The Portland heavy industrial station I-1 and USA commercial station UC2 showed a high number of exceedances for dissolved Cd. The other stations showed few exceedances. The percentage of exceedances for all the stations for dissolved Cd is relatively low (5%).

Dissolved Cu and Zn consistently exceeded the acute water quality criteria for a majority of the stations for all land uses except for open space. The percentage of exceedances tended to be higher for industrial (Cu: 40%, Zn: 66%) and transportation (Cu: 43%, Zn: 61%). While commercial (Cu: 32%, Zn: 38%) and residential (Cu: 36%, Zn: 43%) land use concentrations exceeded Cu and Zn less frequently, but still often. In general the pipe stations did exceed standards more frequently, but urbanized streams/open earthen channels also exceeded the Cu and/or Zn criteria frequently, including at the A-3 channel (Eugene I1) and Amazon Creek (Eugene M1) in Eugene; Fanno Creek in Portland (Portland R1); and Fanno Creek in USA jurisdiction (USA UM1). However, Johnson Creek in Portland (M2) did not exceed either the Cu or Zn criteria values in any of the storm samples collected.

Approximately 17 to 33 percent, varied by land use, of the EMCs were found to exceed the proposed industrial NPDES permit stormwater quality benchmark for TSS (NPDES 1200-Z). Exceedances are measured at almost all stations except for the residential stations in Clackamas

County, Redleaf (residential) in Salem and two USA mixed land use stations Ul2 and UR1. Industrial stations and transportation stations have the highest percentage of exceedances, while the open space station has the lowest.

A comparison of the results for oil and grease indicates that most of the exceedances occurred at transportation stations. Data from other land use stations (except for open space) also show some exceedances, but the percentage is relatively low as compared to transportation.

4.2 COMPARISON OF RESULTS WITH OTHER STUDIES

In order to understand how Oregon stormwater quality compares with other data collected nationally, the results of two national programs and one west coast program were evaluated against the ACWA data. ACWA data were compared with available data from the National Urban Runoff Program (NURP) study (EPA, 1983); the Federal Highway Administration's (FHWA) Highway Runoff Study (Driscoll et. al., 1990) and the California Bay Area Stormwater Management Agencies Association Monitoring Data Analysis (WCC, 1996). Tables 4-4 through 4-8 present the comparisons between site median concentrations (SMCs) from different land use stations in the ACWA data, the NURP study data, the FHWA study data and Bay Area data for TSS; BOD_5; COD; total and dissolved P; TKN, NO_3+NO_2 as N; and total and dissolved Cu, Pb and Zn. Prior to performing comparisons, a similar procedure to that explained in section 3.2 for pooling data was employed to assess station grouping. For this analysis of the data, mixed land use stations were included. In general, the ACWA data were comparable with the national data.

For the residential land use, concentrations of conventional pollutants, nutrients and heavy metals in stormwater discharges from the grouped residential stations were generally lower than national data. Portland's R-1 station was excluded from the group because it was statistically different from the other residential stations. This statistical difference may be explained by the station's physical characteristics. It is the only instream station in the group. However, its values are also lower than national data.

For the commercial land use, conventional pollutant (TSS, BOD_5 and COD) concentrations from the grouped commercial stations were similar to data collected in other studies. Total phosphorous concentrations from Oregon's commercial land use were higher than NURP, but lower than Santa Clara data. The TKN concentrations and heavy metal concentrations were generally lower than the other studies, although Cu and Zn values were close to national and Santa Clara data. USA station UC3 was excluded from the study as this in-pipe station experienced sediment depositions problems during the monitoring period.

Data from industrial stations were thought to be highly dependent on the types of industries monitored and NURP did not attempt to estimate median pollutant concentrations for industrial land uses. However, the industrial stations in Oregon were grouped together and compared with Santa Clara data. The results show that the ACWA data are usually lower than data from Santa

Clara for TSS, nutrients, and metals, but higher than Santa Clara for BOD_5. Cu data was relatively close to Santa Clara values. Eugene's I2 station was not included in the industrial group since it is located at the downstream end of a wetland, which provides water quality treatment.

TSS concentrations from the transportation land use are similar to FHWA data, but lower than Santa Clara data. Results for heavy metals and COD are the opposite, ACWA metals data are similar to Santa Clara data, but much lower than the FHWA data.

Relatively lower SMCs were observed for the mixed land use for all the pollutants studied, as compared with the NURP studies. This trend follows the same trend as residential and commercial sites. Portland's station M-1 was found to be statistically different from the other mixed stations and was not included in the grouping. Unlike other stations that were excluded for land use grouping, the M-1 site did not have any identifiable characteristics that could account for it's statistical difference.

Portland's instream station OP-1 was used to represent open space land use in the comparison. Although the lack of information from additional open space sites in Oregon makes it difficult to draw a conclusion, a comparison is made between OP-1 and open space sites in the NURP and Santa Clara data. The metal and TSS concentrations from OP-1 were lower than NURP data, but similar to Santa Clara data. The total phosphorus concentration was higher than NURP data, but lower than Santa Clara data. Results for remaining parameters were lower than the data collected by other studies.

One of the main purposes of this study was to assess the value of continued land use monitoring in Oregon for the purpose of characterizing typical land use based concentrations of stormwater runoff. In Section 3, it was determined that land use data was sufficient to be able to establish statistically significant differences in stormwater quality between the different land uses monitored. The purpose of this section is to show the estimated value of more land use data in reducing the confidence intervals of the land use mean concentrations (e.g. improving the estimates of land use runoff average concentrations). This was evaluated by estimating what the expected reduction of the confidence interval of the estimate of the mean concentration would be with the equivalent of one more years worth of sampling data (3 storms at each station).

A statistical test to determine the estimated effects of increased sample sizes on the 90% confidence interval for the mean was conducted to evaluate the value of obtaining additional land use data (Gilbert, 1987). This was conducted for residential, commercial, in-pipe industrial and transportation land use pooled data sets. The confidence limits (two-sided) give an interval in which the true mean is expected to lie between, within a specified (90% probability) confidence. The estimated confidence interval for the existing data can be compared with intervals estimated for different sample sizes to determine the expected improvement in estimating the mean (this analysis assumes that the variance of the data set does not change).

In the test, the 90% confidence intervals for the means were calculated first based on the existing sampling data for each of the different land uses. Then, three additional stormwater sampling events were presumed to be added to each station, thus increasing the sample size for a specific land use by the number of stations multiplied by three. The added station data were assumed to follow the same lognormal distribution for the land use type and it was assumed that the variability in the data was similar. The expected 90% confidence interval was then re-calculated based on the increased "pseudo" sample sizes for each land use type. The difference between the confidence limits of the existing data set and what would be expected for the increased data set indicates the effect that increasing sample size would likely have on decreasing the uncertainties involved in estimating the mean. Due to the asymmetric characteristic of the 90% confidence limits for the mean (caused by the lognormal distribution of the data), the span of confidence limits is calculated as the difference between the upper 90% confidence limit and lower 90% confidence limit, and is used as an indicator for the improvement on accuracy for the mean's prediction. Tables 5-1 and 5-2 show the test results for TSS and total Cu. Note that adding three data points (sampling events) to each station leads to different increases in the sample size for different land uses. However, this increase in data conforms to an additional year's worth of permit specified monitoring.

As expected, with the additional sampling points, the confidence intervals were narrowed. However, the degree of change was relatively low as compared to the percent increase in data points needed. The decrease in the "spread" of confidence limits was in the range of 13% to 17%, with transportation land use having the largest decrease rate, and commercial land use having the lowest. The narrowing effect on confidence intervals can also be expressed by changes in pollutant concentrations. For example, three additional data points for each station would result in an approximately 3 mg/l reduction in the mean TSS 90% confidence interval for the residential and commercial land uses, where the number is about 12 mg/l for the industrial and transportation land uses.

To achieve the relatively small percentage improvements in the estimate of the mean concentrations, a significantly larger percentage increase in data is required. For example, to achieve the 13% improvement in the estimate of the mean concentration for total Cu for commercial land uses would require about 30% more data and to improve the estimate for TSS for transportation by 17% would require about 39% more data.

Taking into account the costs and efforts required to obtain additional monitoring data and the degree of improvement on estimation of the mean, increasing sampling frequency at stormwater stations does not appear to be cost-effective.

6.1 INTRODUCTION

This section presents a summary of estimated typical costs for the major tasks associated with land use based stormwater monitoring. Actual costs for specific phases of a municipalities NPDES stormwater program are very difficult to obtain because of agencies accounting methods. Agencies typically do not track detailed project budgets. In addition, project budgets typically have overlap between tasks or include costs for work not associated with the stormwater program. Therefore, because accurate budget information could not be obtained for the NPDES MS4 permittees monitoring programs, cost estimates based upon Woodward-Clyde's experience with design and implementation of stormwater monitoring programs for Eugene, Gresham, Portland, and Unified Sewerage Agency, were made for conducting the primary stormwater monitoring tasks. This general cost information is intended to provide guidance on the expense of stormwater data collection for assessing the benefits of continued land use monitoring.

6.2 MONITORING COST ESTIMATES

Cost estimates for specific monitoring tasks were developed assuming a five station automated system that is capable of collecting flow-weighted composite samples. Table 6-1 shows the estimated monitoring costs for a five station system. As can be seen in Table 6-1, the costs for each task have been shown as a range with maximum and minimum values specified. The cost table has also been divided to provide a total for the capital investment costs associated with the monitoring program and to provide a total for the costs to conduct a sampling event.

The capital investment for a sampling program has a large degree of variability, which is generally associated with the equipment and installation of equipment. Often times, site selection and the monitoring protocols specified in the monitoring plan can dictate the type of equipment and the station design requirements. For example, a system that can be mounted in a manhole and does not require an equipment enclosure or protective conduit for sensor lines may reduce the capital cost. However, when selecting a site it should also be considered how a station design effects the recurring costs associated with storm event monitoring. For example, although the manhole station may have a lower capital costs its operational costs may be higher since it requires crews entering the manhole for installation and maintenance of the station to be confined space entry trained and manholes are often located in streets where the use of traffic control or other safety equipment is essential.

Stormwater monitoring implementation costs are estimated to range from about $55,000 to $123,000. To conduct 3 sampling events per year is estimated to cost between $30,000 to $42,000. Data reporting and analysis, station maintenance, and equipment replacement bring the annual estimate of costs up to $45,000 to $66,000.

Stormwater monitoring activities can include chemical, biological, and physical measurements and observations. The existing permit monitoring program focused primarily on chemical measurements with some physical monitoring of flows required to properly composite the samples collected over the course of a storm event. The primary objective satisfied by the program was to identify land use based concentrations for the purpose of characterizing potential land use based contributions and sources of pollutants to the municipalities receiving waters. In the future the data may be useful for assessing trends. This could include assessments of the effects of the implementation of the NPDES permit stormwater management plans and/or specific BMPs applied to one of the previously monitored watersheds. In watersheds where additional development is occurring, the stations may be used to assess the impacts of further urbanization and/or land use conversion (e.g. densification). However, given the variability in the data, assessing trends will be resource intensive unless changes are large (over 20 to 30%).

However, the continuance of devoting large amounts of resources to land use monitoring is probably not the best use of limited resources. There are a number of other monitoring options that would likely provide additional useful information that at this time is more valuable with respect to making better stormwater management decisions.

There are a large variety of monitoring methods, techniques, strategies, and applications to choose from. Prior to selecting monitoring methods, monitoring objectives should be established. Potential monitoring objectives could include:

<u>Characterize Land Use Concentrations/Loadings</u>

<u>Identify/Detect Specific Sources of Stormwater Pollution</u>

- Pesticide use areas
- Illicit dumping/connections
- Automotive sources
- Construction
- Specific messy housekeeping sites

<u>Assess Potential Receiving Water Impacts from Stormwater</u>

- Biological impact cause study
- Habitat destruction- physical stress
- Channel stability problems
- Establish and assess reference creeks

<u>Determine Amount of Treatment/Control Needed</u>

<u>Evaluate Structural BMP Performance - Pollutant Removal/Hydrologic Control and/or Biological Health Improvement</u>

- Compost filter
- Sand filter
- Wet pond
- Dry-extended detention pond
- Grass swale
- Bio-retention swale
- Infiltration trenches
- Infiltration ponds
- Catch basins inserts
- Wetland systems
- Pervious pavement
- Innovative BMPs (e.g. roof gardens)

Assess Non-Structural BMP Performance

- Education programs and surveys
- Maintenance
- Source control

Assess Ambient/Low-Flow Contributions

- Background concentrations in low flows
- Groundwater sources

Determine Treatability of Stormwater

- Conduct settling tests
- Conduct size fraction analysis and associated pollutant tests
- Study media ability to uptake pollutants

Assess Use of Biological Indicators vs. Chemical Measurements

In meeting one or more of these objectives a variety of monitoring approaches might be applied. For chemical, it could range from use of simple test kits and/or collecting grab samples to the more complicated flow-weighted composite samples. Physical assessments could include hydrology measurements, physical habitat surveys, aerial photography, and stream geomorphology measurements. Biological approaches could include bioassays/toxicity testing, aquatic invertebrate population analyses, and fish tissue analyses. Specific studies to meet the objectives listed above could include any of the different monitoring approaches above in combinations.

The primary purpose of this study was to evaluate what has been learned from the urban stormwater monitoring data collected to date by the Oregon Municipal Stormwater NPDES applicants and permitted agencies and specifically to assess the value of the permits continued requirement for primarily land use based stormwater monitoring. Presented below is a brief listing of the results obtained from this study.

- An Oregon statewide urban stormwater water quality monitoring database has been developed that will allow users to more readily access this information for the purposes of exploring what has been and can be learned about urban stormwater water quality. The database can be used as a tool for continued data storage as new data are collected. It can serve as a tool to allow agencies to benefit from stormwater data collected in other Oregon jurisdictions.
- Statistical analyses were performed on stormwater water quality data from stations with similar land uses for TSS, total Cu, dissolved Cu and total Zn to determine if they could be pooled together for assessing whether stormwater from different land uses shows different concentrations and, therefore, loading rates. After excluding several of the stations due to statistical and physical site characteristics, it was found that the data for in-pipe industrial, instream (channel) industrial, transportation, commercial, and residential stations could be pooled. This allowed the formation of larger, more robust data sets for evaluating whether stormwater quality from different land uses appears to be different. The data set also included one open land use station (Balch Creek in Portland), which was large enough (i.e., had a sufficient amount of data points) for including it in the analysis.
- Generally, it was determined that stormwater concentrations from different land uses appeared to be statistically different from each other. Specifically, for urban stormwater water quality it was found that:
    - Residential land use appeared to be statistically different from all other land uses.
    - Commercial land use was found to be similar to the instream industrial land use only.
    - Instream industrial land use was similar to transportation and commercial land uses.
    - In-pipe industrial land use was similar to the transportation land use only.
    - Transportation land use was similar to both the in-pipe and instream industrial land uses.
    - Open space land use, like the residential land use, appeared to be statistically different (lower) from all other land use types.

    Note: These conclusions are based on the assumption that if any land use type was significantly different from another land use for more than 2 of the 4 parameters studied it could be considered as significantly different from that land use.
- In terms of pollutant concentrations, the in-pipe industrial land use showed the highest pollutant concentrations for all the parameters studied, followed by transportation, instream

industrial, commercial and residential. As expected, open space represented lowest pollutant concentrations for all the constituents analyzed.

- The findings of differences between stormwater quality data from different land uses could serve for the basis of improving the implementation of the stormwater management plans (e.g., better targeted control measures, etc.) and potentially for improving the basis for agency cost recovery for stormwater services (e.g., assessing stormwater fees based partially upon expected land use water quality, etc.).
- Total P showed a high variability among stations with similar land uses. Therefore, the station data for total phosphorus were grouped by agency to evaluate whether local conditions (soils) could be affecting the amount of phosphorus in stormwater (rather than land uses). Results indicate that Portland and Eugene stations exhibit relatively higher phosphorus concentrations, while Gresham and Salem data are comparatively low. USA and Clackamas data were in the middle range. Eugene's and Portland's stations did show a high variability amongst each other indicating that there are likely more localized differences in available phosphorus. A potential additional analysis step would be to determine the dominant native soil types, including natural phosphorus content, within each of the monitored watersheds and to compare this information with station observed stormwater phosphorus concentrations. This would help to determine whether or not the soil phosphorus levels are a dominant factor affecting urban stormwater concentrations rather than land use.
- The storm event mean concentration data were compared to in-receiving water quality standards. It is important to note that most of the stations are pipe stations and the analysis is for comparative purposes. Exceedances of water quality standards and criteria were observed at developed land use stations for TSS, oil and grease, dissolved Cu, dissolved Zn, dissolved Cd, dissolved Pb and dissolved Ag. Industrial and transportation land use stations had the highest percentage of exceedances for most parameters studied; commercial and residential stations also had a relatively high percentage of exceedances for dissolved Cu, dissolved Pb and dissolved Zn; the open space station always had the lowest number of water quality exceedances for all the parameters studied.
- The urban stream stations that were comprised primarily of urbanized watersheds also showed a significant level of exceedances of water quality criteria for dissolved Cu and Zn (Fanno Creek in Portland and Amazon Creek in Eugene).
- ACWA data were compared to data collected under the NURP, the FHWA Study and the Santa Clara NPDES permit program. Overall, the ACWA data were comparable with the other studies, and the results for most parameters for the different land uses were generally lower than those in other studies.
- The adequacy of the current data was evaluated based on the relationship between sample size and 90% confidence intervals for the mean for each of the land use pooled data. Results indicated that increasing monitoring frequency by sampling three more storm events for each station will not dramatically decrease the uncertainties in the estimation of mean concentrations for land uses.

- Given the typical costs for continued land use monitoring programs, it is recommended that agencies should consider other potential monitoring objectives and strategies. Some continued land use monitoring may be useful for assessing trends, but other types of monitoring would likely result in more useful information for improving stormwater management programs.

There are a number of potential additional analyses that could be performed with the data to improve the knowledge of stormwater characteristics. These analyses would be useful for improving the understanding of potential BMP effectiveness, understanding the implications of the data for stormwater pollutant loads modeling, and for assessing the potential magnitude of water quality criteria exceedances. These include:

- Performing an analysis of the typical partitioning (dissolved vs. particulate phase) of urban stormwater pollutants and how this partitioning changes (or not) with increasing total concentration.
- Performing an analysis of the relationship of TSS to other pollutants (e.g. how good of a predictor is TSS of other pollutants).
- Evaluating the magnitude of the exceedances of water quality criteria to gage the potential severity of stormwater discharges.
- Assessing whether the number of dry days before a storm affects the quality of the stormwater.
- Determine whether or not soil phosphorus levels are a dominant factor affecting urban stormwater concentrations.

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Table 2-1a: Residential Land Use Station Characteristics

Agency	Station Designation	Drainage Area (Acres)	Land Use Type (Percentage) Agri. (Estimated Percentage)[1]	Open	Resi.	Comm.	Receiving Water	Conveyance	# of Storms
Residential Land Use									
City of Eugene	R1	377					A-2 Channel	Piped System	15
City of Gresham	K-4	73			100		Columbia Slough	Piped System	6
City of Portland	R-1	1400			95	5	Fanno Creek	Open Channel	12
	R-2	85			100		Columbia Slough	Piped System	11
City of Salem	Redleaf	72			100		Walnut Creek	Piped System	5
Clackamas County	Bell Station	15			100		Johnson Creek	Piped System	1
	Lake Oswego	120			100		Lake Oswego Canal	Piped System	5
	Milwaukie	165			100		Johnson Creek	Piped System	3
	Oregon City	50			100		Coffee Creek	Piped System	5
USA	UR2	90	6	1	93		Hedges	Piped System	8

[1] where available

Table 2-1b: Commercial Land Use Station Characteristics

Agency	Station Designation	Drainage Area (Acres)	Land Use Type Percentage (Estimated)[1] Agri.	Resi.	Comm.	Receiving Water	Conveyance	# of Storms
Commercial Land Use								
City of Eugene	C1	380				Willamette River	Piped System	14
City of Gresham	M-16	64		10	90	Johnson Creek	Piped System	6
City of Portland	C-1	35			100	Columbia River	Piped System	12
	C-2	75		15	85	Willamette River	Piped System	13
City of Salem	Cottage	40			100	Pringle Creek	Piped System	5
Clackamas County	Wilson Road	41			100	Boeckman Creek	Piped System	5
USA	UC1b	200		20	80	Dawson Creek	Piped System	7
	UC2	82	18		82	Fanno Creek	Piped System	8
	UC3	325		10	90	Council Creek	Piped System	7

[1] where available

Table 2-1c: Industrial and Transportation Land Use Station Characteristics

Agency	Station Designation	Drainage Area (Acres)	Land Use Type (Percentage) Light Indus. (Estimated Percentage)[1]	Heavy Indus.	Resi.	Trans.	Receiving Water	Conveyance	# of Storms
Industrial Land Use									
City of Eugene	I1	889					A-3 Channel	Open Channel	12
City of Portland	I-1	46		100			Willamette River	Piped System	11
City of Eugene	I2	1,011					Bertlesen Slough	Open Channel	14
City of Portland	I-2	49	100				Willamette River	Piped System	8
City of Salem	Edgewater	35	100				Willamette River	Piped System	4
Clackamas County	Cow Creek	495	80		20		Cow Creek	Open Channel	5
USA	UI1	60	100				Fanno Creek	Piped System	1
Transportation Land Use									
City of Portland	T-1	10				100	Willamette River	Piped System	12
ODOT	Eugene	18.2				100	Willamette River	Piped System	5
	Portland	23.1				100	Willamette River	Piped System	6

[1] where available

Table 2-1d: Mixed and Open Land Use Station Characteristics

Agency	Station Designation	Drainage Area (Acres)	Land Use Type (Percentage)					Receiving Water	Conveyance	# of Storms
			Agri.	Open	Indus.	Resi.	Comm.			
			(Estimated Percentage)[1]							
Mixed Land Use										
City of Eugene	M1	886						Willamette River	Piped System	16
	M2	3267						Fern Ridge Reservoir	Open Channel	21
City of Gresham	E-3	292		3	52	45		Columbia Slough	Piped System	6
	I-13	789		3		61	36	Columbia Slough	Piped System	6
City of Portland	M-1	91		5	5	60	30	Columbia Slough	Piped System	13
	M-2	33000						Johnson Creek	Open Channel	13
City of Salem	Commercial	31				42	58	Pringle Creek	Piped System	6
USA	UI2	120	25		40		35	Fanno Creek	Piped System	7
	UM1	19850	10	1	5	74	10	Fanno Creek	Open Channel	6
	UR1	120	20			68	12	N. Johnson Creek	Piped System	6
Open Land Use										
City of Portland	OP-1	1500		100				Balch Creek	Open Channel	8

[1] where available

Figure 3-1. Example Individual Station Log-Normal Probablility Plots

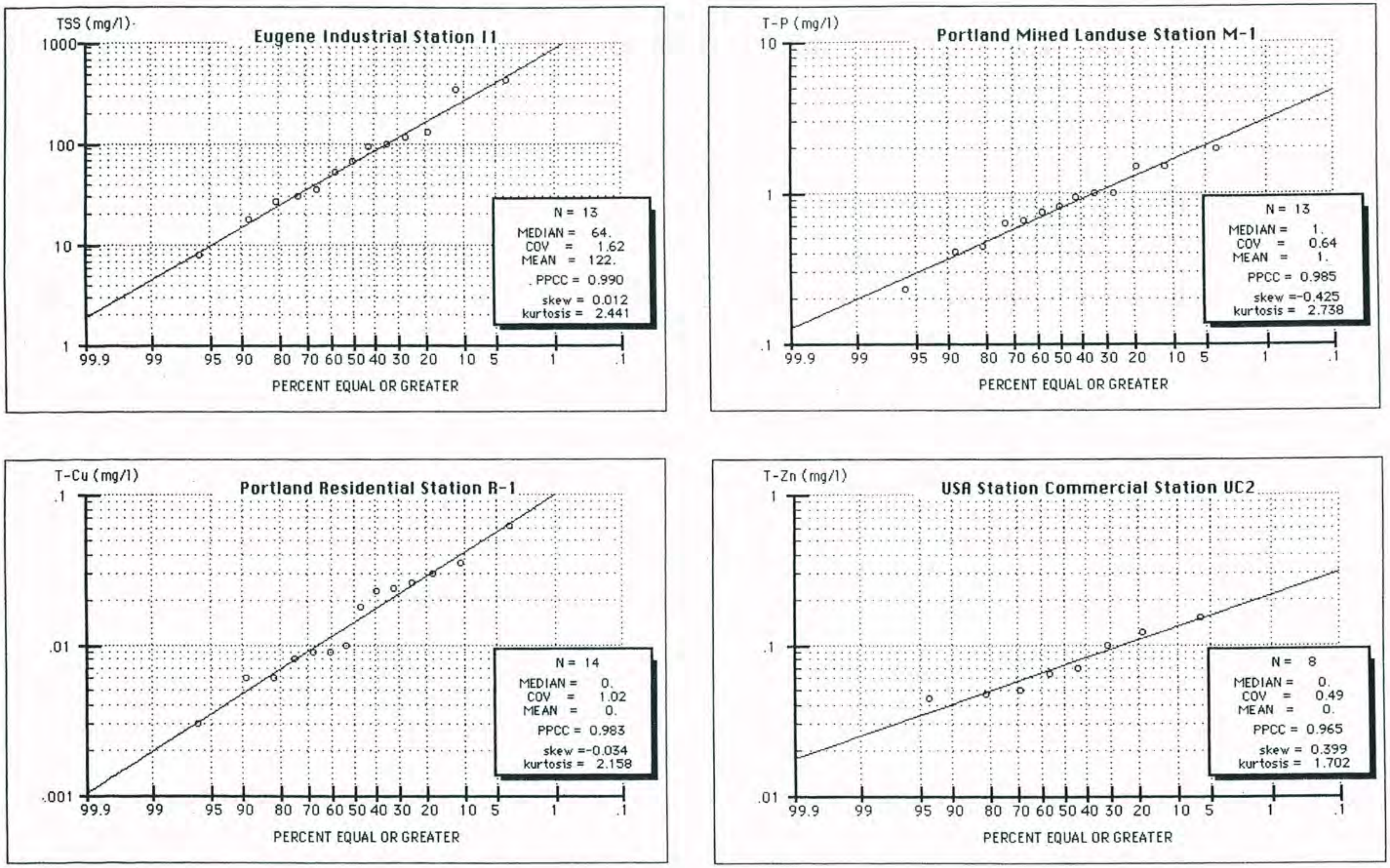
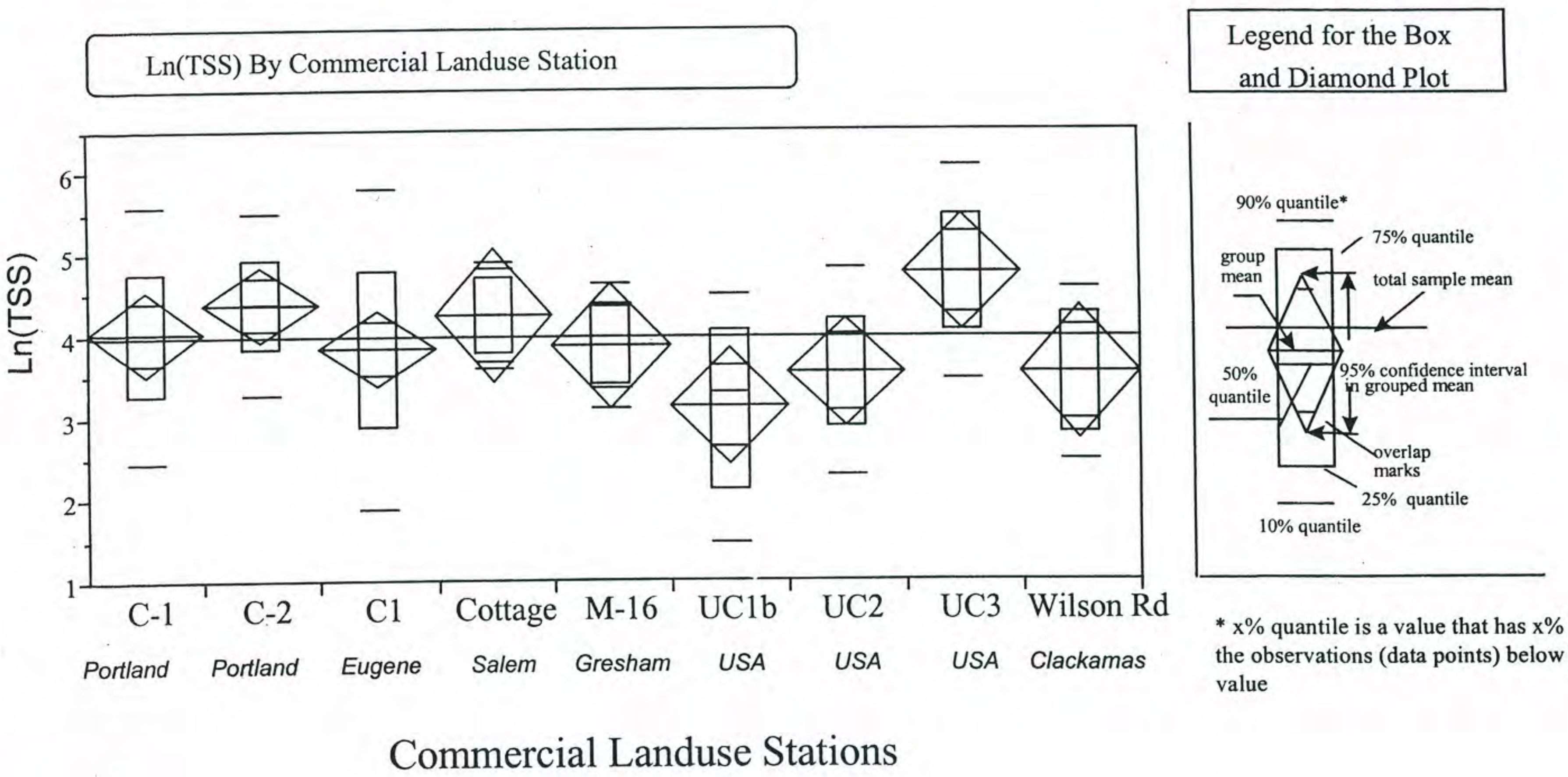
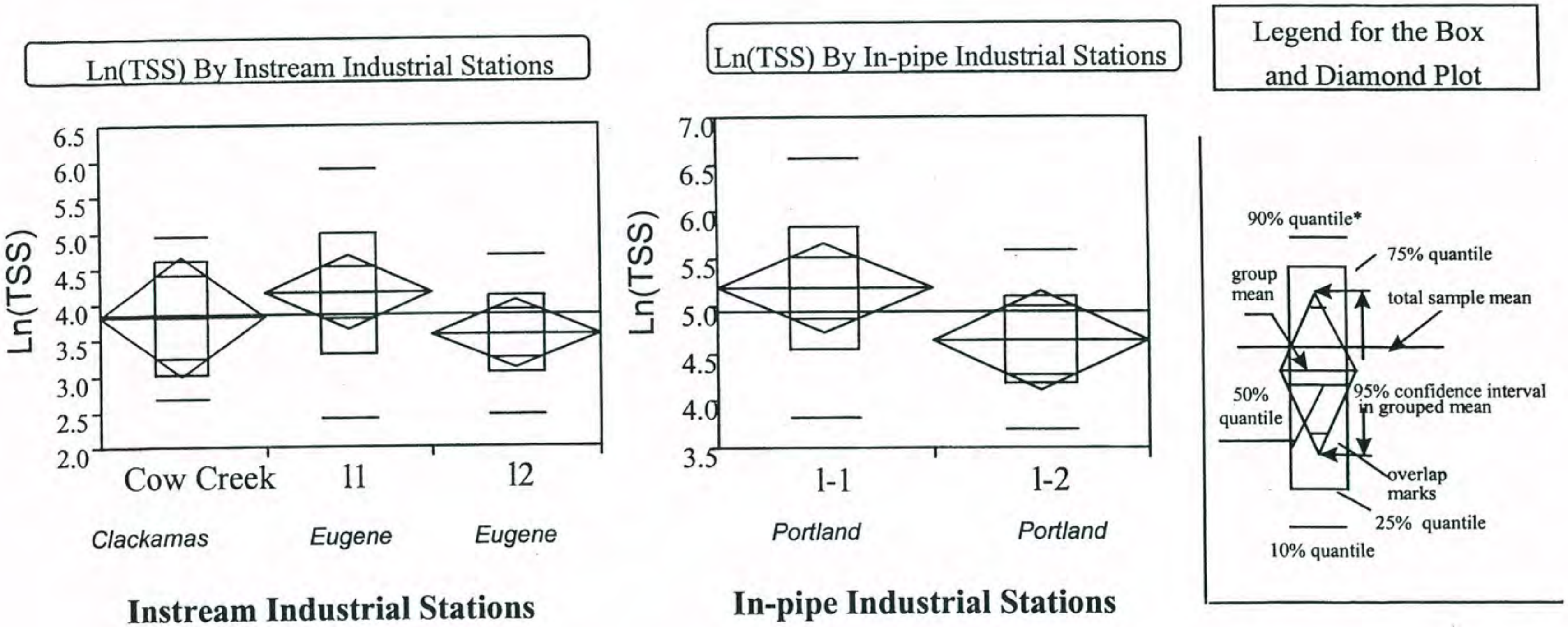


Figure 3-2: Commercial Land Use Station TSS Distribution Box and Diamond Plots



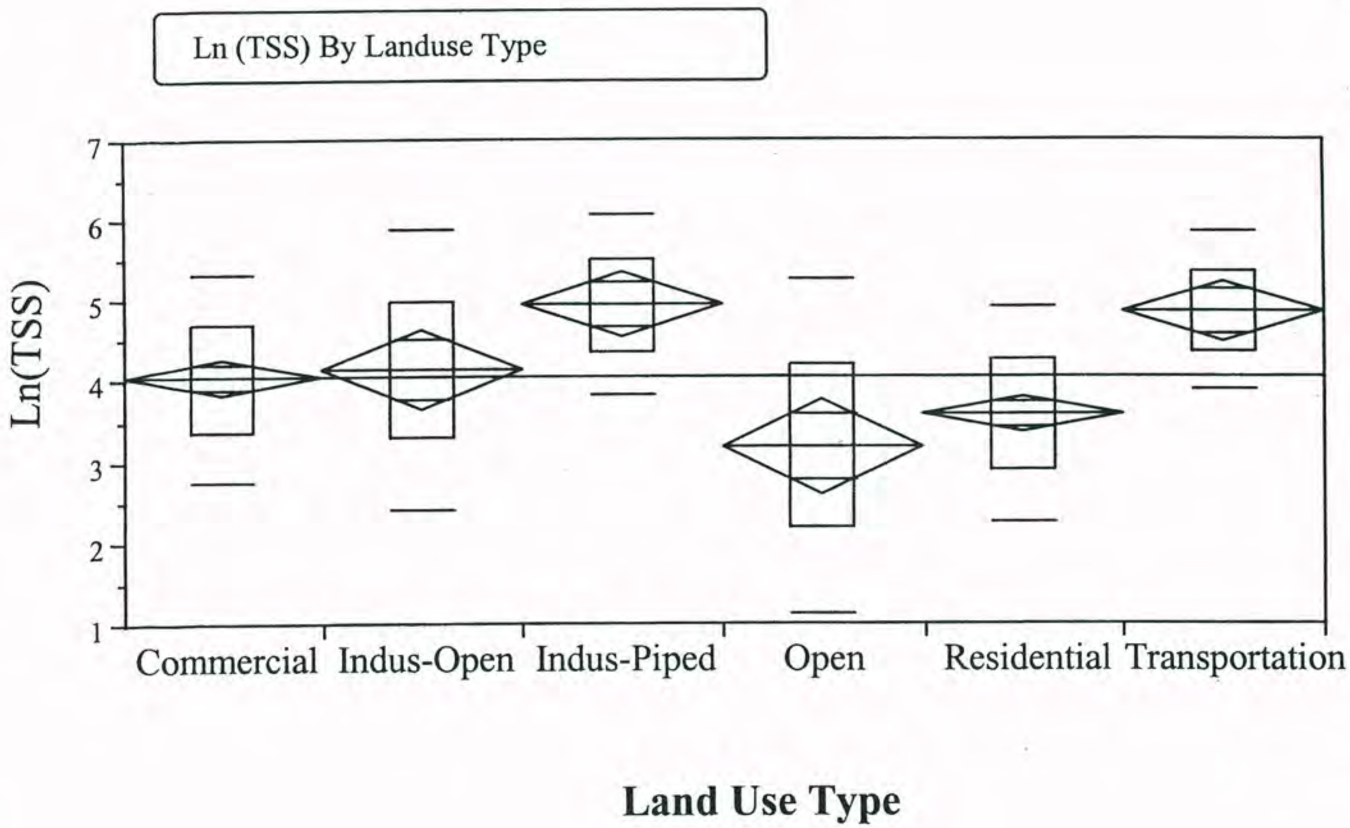
* x% quantile is a value that has x% of the observations (data points) below its value

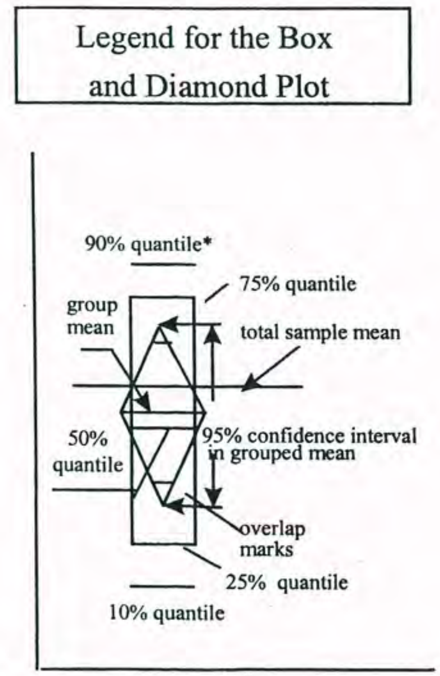
Figure 3-3: Industrial Land Use Station TSS Distribution Box and Diamond Plots



* x% quantile is a value that has x% of the observations (data points) below its value

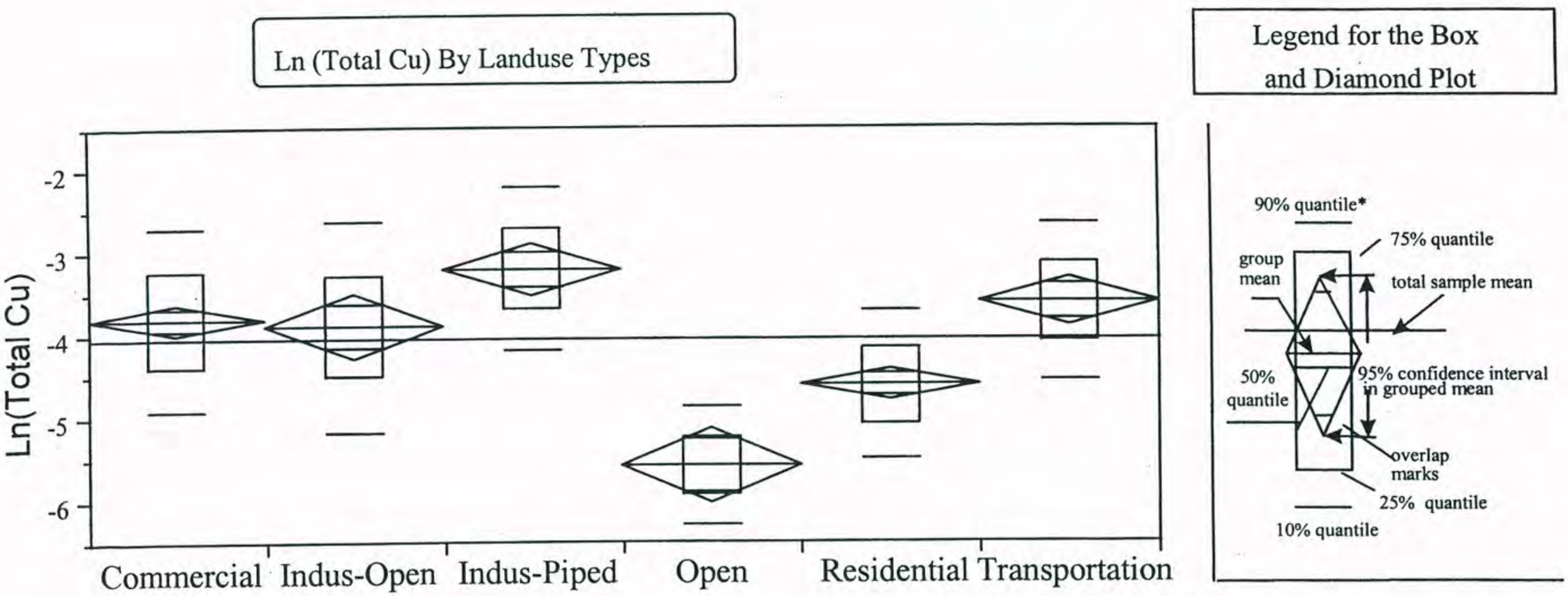
Figure 3-4: Pooled Land Use Distribution Box and Diamond Plots for TSS





* x% quantile is a value that has x% of the observations (data points) below its value

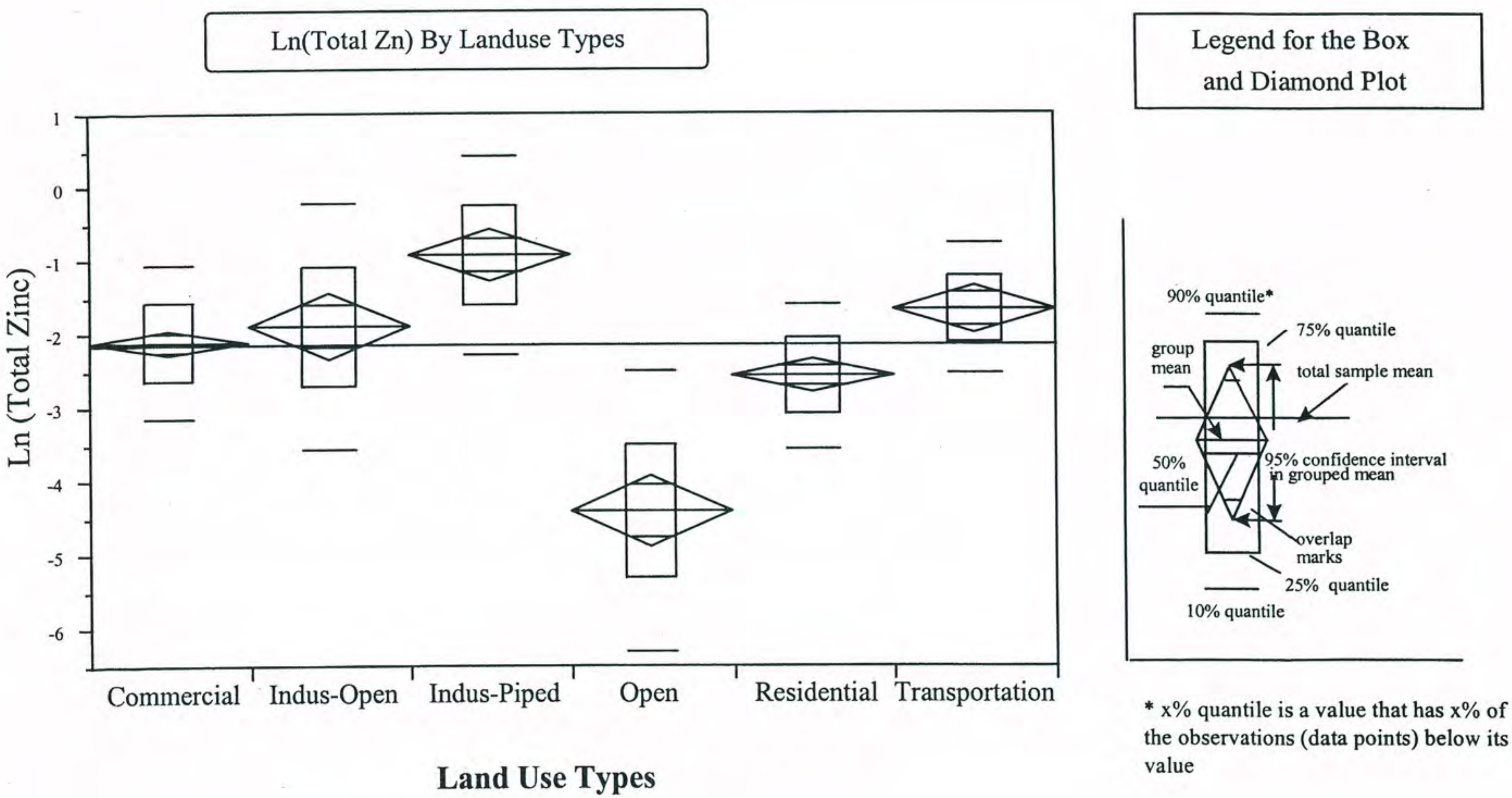
Figure 3-5: Pooled Land Use Distribution Box and Diamond Plots for Total Copper



* x% quantile is a value that has x% of the observations (data points) below its value

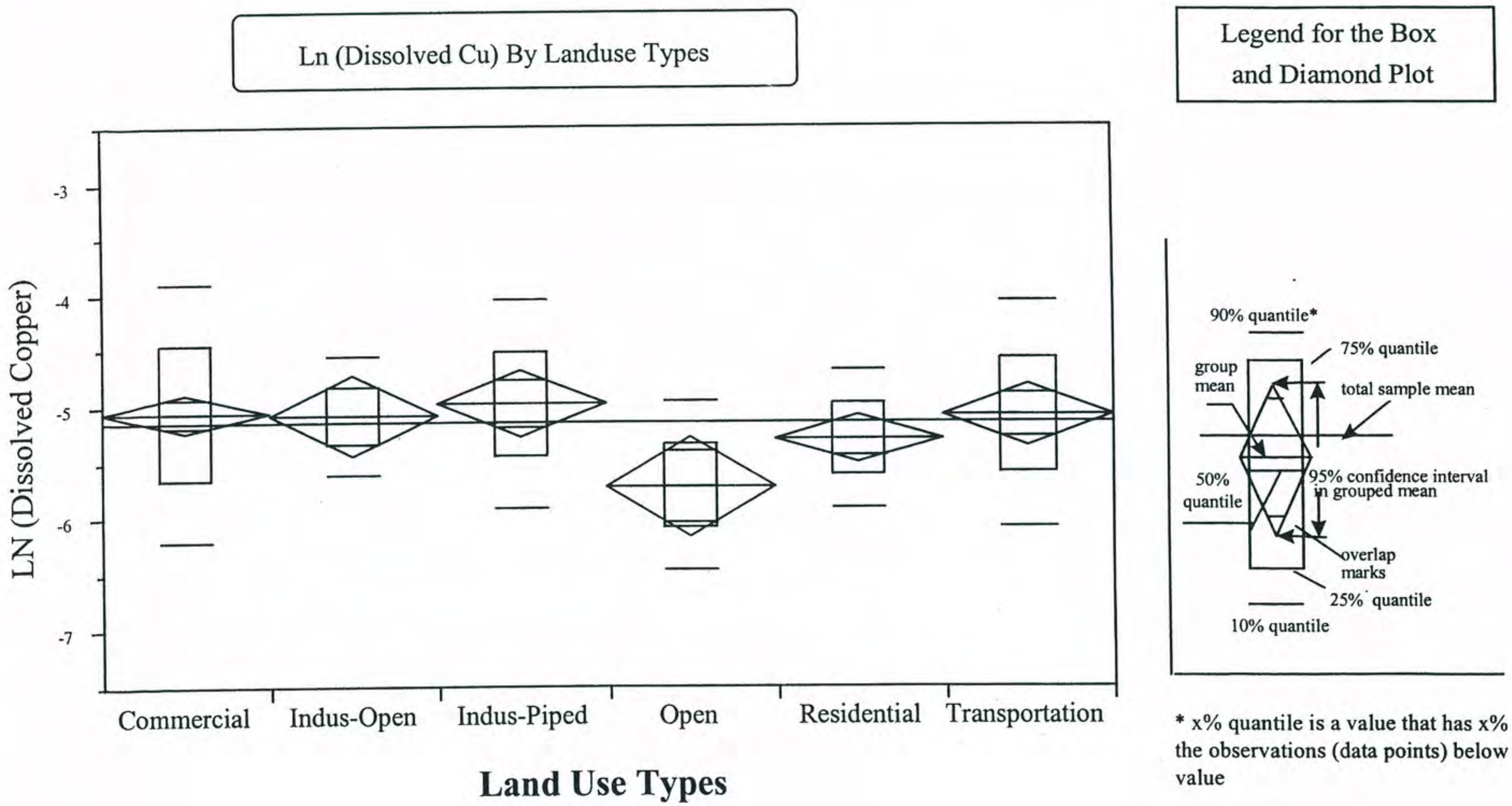
Land Use Types

Figure 3-6: Pooled Land Use Distribution Box and Diamond Plots for Total Zinc



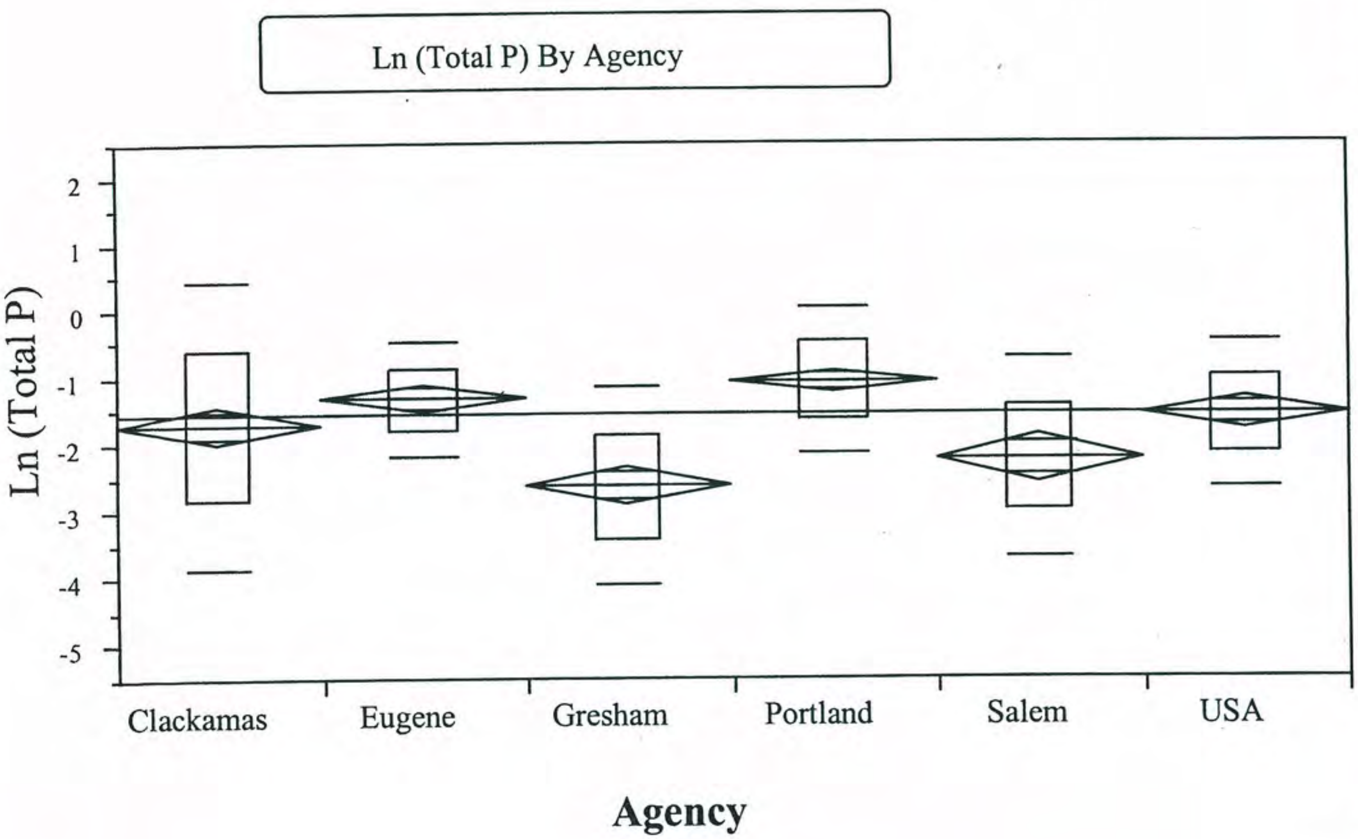
* x% quantile is a value that has x% of the observations (data points) below its value

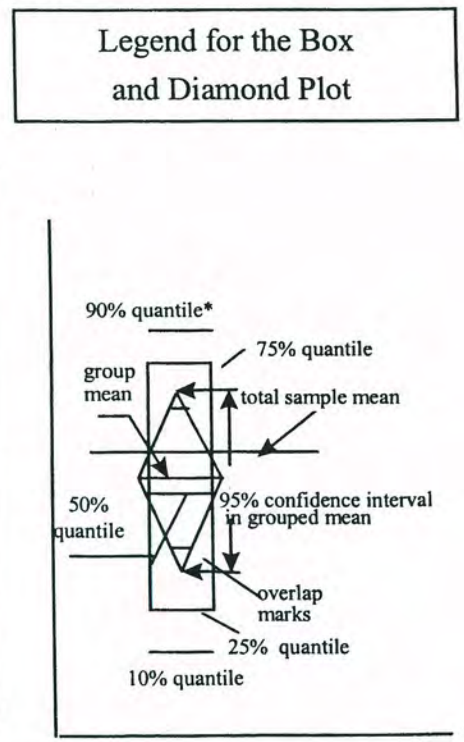
Figure 3-7: Pooled Land Use Distribution Box and Diamond Plots for Dissolved Copper



* x% quantile is a value that has x% of the observations (data points) below its value

Figure 3-8: Pooled by Agency Total Phosphorus Distribution Box and Diamond Plots





* x% quantile is a value that has x% of the observations (data points) below its value

Table 4.1a Percentage of Detections and Exceedances of Receiving Acute Water Quality Criteria for Dissolved Cadmium, Chromium and Copper[1] (Continued)

Agency	Station	Cadmium-d			Chromium-d			Copper-d		
		#Sam	%Detect	%Exceed	#Sam.	%Detect	%Exceed	#Sam.	%Detect	%Exceed
Residential Land Use										
City of Eugene	R1	16	0%	0%	10	40%	0%	16	63%	31%
City of Portland	R-1	13	8%	0%	8	75%	0%	13	92%	23%
	R-2	11	9%	0%	8	25%	0%	11	91%	45%
USA	UR2	7	0%	0%	7	71%	0%	7	100%	57%
Summary		47	4%	0%	33	52%		47	83%	36%
Mixed Land Use										
City of Eugene	M1	12	17%	0%	6	33%	0%	12	75%	17%
	M2	12	8%	0%	6	50%	0%	12	50%	17%
City of Portland	M-1	13	38%	0%	8	75%	0%	13	92%	31%
	M-2	12	0%	0%	8	75%	0%	12	100%	0%
USA	UI2	5	0%	0%	5	100%	0%	5	100%	0%
	UM1	5	20%	0%	5	20%	0%	5	100%	20%
	UR1	4	0%	0%	4	75%	0%	4	100%	0%
Summary		63	14%	0%	42	62%	0%	63	84%	14%
Open Space Land Use										
City of Portland	OP-1	9	11%	0%	6	50%	0%	9	89%	0%

[1]Criteria are hardness dependent and therefore vary for each storm event

Table 4.1b Percentage of Detections and Exceedances of Receiving Acute Water Quality Criteria for Dissolved Lead, Nickel, Silver and Zinc[1]

Agency	Station	Lead-d			Nickel-d			Silver-d			Zinc-d		
		#Sam.	%Detect	%Exceed	#Sam.	%Detect	%Exceed	#Sam.	%Detect	%Exceed	#Sam.	%Detect	%Exceed
Industrial Land Use													
Eugene	I1	13	54%	0%	8	50%	0%	13	0%	0%	13	100%	54%
Portland	I-1	12	67%	0%	9	100%	0%	12	25%	8%	12	100%	100%
Eugene	I2	16	44%	0%	10	70%	0%	16	0%	0%	16	100%	38%
Portland	I-2	8	63%	0%	5	80%	0%	8	25%	0%	8	100%	100%
USA	UI1	1	0%	0%	1	0%	0%	1	0%	0%	1	100%	0%
Summary		50	54%	0%	33	73%	0%	50	10%	2%	50	100%	66%
Transportation Land Use													
Portland	T-1	12	83%	0%	8	100%	0%	12	8%	0%	12	100%	75%
ODOT	Eugene	5	40%	0%							5	100%	20%
	Portland	6	50%	17%							6	100%	67%
Summary		23	65%	4%	8	100%	0%	12	8%	0%	23	100%	61%
Commercial Land Use													
Eugene	C1	15	60%	0%	9	33%	0%	15	0%	0%	15	100%	60%
Portland	C-1	12	75%	8%	9	78%	0%	12	8%	0%	12	100%	92%
	C-2	14	86%	0%	10	90%	0%	14	7%	0%	14	100%	0%
USA	UC1b	6	33%	0%	6	33%	0%	6	0%	0%	6	100%	0%
	UC2	7	29%	0%	7	29%	0%	7	14%	0%	7	100%	43%
	UC3	6	0%	0%	6	33%	0%	6	0%	0%	6	100%	0%
Summary		60	57%	2%	47	53%	0%	60	5%	0%	60	100%	38%

[1]Criteria are hardness dependent and therefore vary for each storm event

Table 4.1b Percentage of Detections and Exceedances of Receiving Acute Water Quality Criteria for Dissolved Lead, Nickel, Silver and Zinc[1] (Continued)

Agency	Station	Lead-d			Nickel-d			Silver-d			Zinc-d		
		#Sam.	%Detect	%Exceed	#Sam.	%Detect	%Exceed	#Sam.	%Detect	%Exceed	#Sam.	%Detect	%Excee
Mixed Land Use													
Eugene	M1	12	42%	0%	6	33%	0%	12	0%	0%	12	100%	25%
	M2	12	42%	0%	6	67%	0%	12	0%	0%	12	75%	8%
Portland	M-1	13	54%	0%	8	100%	0%	13	15%	0%	13	100%	62%
	M-2	12	58%	0%	8	63%	0%	12	17%	0%	12	92%	0%
USA	UI2	5	0%	0%	5	20%	0%	5	0%	0%	5	100%	40%
	UM1	5	0%	0%	5	0%	0%	5	0%	0%	5	100%	0%
	UR1	4	0%	0%	4	0%	0%	4	0%	0%	4	100%	0%
Summary		63	38%	0%	42	48%	0%	63	6%	0%	63	94%	22%
Residential Land Use													
Eugene	R1	16	44%	0%	10	50%	0%	16	6%	6%	16	94%	44%
Portland	R-1	13	46%	8%	8	38%	0%	13	23%	0%	13	92%	8%
	R-2	11	45%	0%	8	63%	0%	11	0%	0%	11	100%	55%
USA	UR2	7	0%	0%	7	0%	0%	7	14%	0%	7	100%	86%
Summary		47	38%	2%	33	39%	0%	47	11%	0%	47	96%	43%
Open Space Land Use													
Portland	OP-1	9	44%	0%	6	33%	0%	9	11%	0%	9	89%	0%

[1]Criteria are hardness dependent and therefore vary for each storm event

Table 4.1a Percentage of Detections and Exceedances of Receiving Acute Water Quality Criteria for Dissolved Cadmium, Chromium and Copper[1]

Agency	Station	Cadmium-d			Chromium-d			Copper-d		
		#Sample	%Detect	%Exceed	#Sample	%Detect	%Exceed	#Sample	%Detect	%Exceed
Industrial Land Use										
City of Eugene	I1	13	23%	0%	8	88%	0%	13	62%	15%
City of Portland	I-1	12	83%	58%	9	78%	0%	12	100%	75%
City of Eugene	I2	16	13%	0%	10	100%	0%	16	63%	31%
City of Portland	I-2	8	63%	0%	5	80%	0%	8	100%	50%
USA	UI1	1	0%	0%	1	100%	0%	1	100%	0%
Summary		50	40%	14%	33	88%	0%	50	78%	40%
Transportation Land Use										
City of Portland	T-1	12	42%	8%	8	88%	0%	12	92%	50%
ODOT	Eugene	5	0%	0%				5	100%	0%
	Portland	6	33%	0%				6	100%	67%
Summary		23	30%	4%	8	88%	0%	23	96%	43%
Commercial Land Use										
City of Eugene	C1	15	13%	0%	9	44%	0%	15	80%	80%
City of Portland	C-1	12	58%	0%	9	67%	0%	12	92%	42%
	C-2	14	36%	0%	10	70%	0%	14	93%	0%
USA	UC1b	6	17%	0%	6	67%	0%	6	100%	0%
	UC2	7	43%	43%	7	86%	0%	7	100%	29%
	UC3	6	0%	17%	6	50%	0%	6	100%	0%
Summary		60	30%	7%	47	64%	0%	60	92%	32%

[1]Criteria are hardness dependent and therefore vary for each storm event

Table 4.2 Percentage of Detections and Exceedances of Receiving Water Quality Criteria for Dissolved Antimony, Beryllium, Iron, Selenium and Thallium[1]

Agency	Station	Antimony-d			Beryllium-d			Iron-d			Selenium-d			Thallium-d		
		#Samples	%Detect	%Exceed	#Samples	%Detect	%Exceed	#Samples	%Detect	%Exceed	#Samples	%Detect	%Exceed	#Samples	%Detect	%Exceed
Industrial Land Use																
Summary for Industrial		29	3.4%	0%	28	0%	0%	16	100%	0%	33	3.0%	0%	29	0%	0%
Transportation Land Use																
Summary for Transportation		8	0%	0%	6	0%	0%				8	12.5%	0%	8	0%	0%
Commercial Land Use																
Summary for Commercial		45	6.7%	0%	45	6.7%	0%	26	96.2%	0%	47	8.5%	0%	45	0%	0%
Residential Land Use																
Summary for Residential		31	3.2%	0%	28	3.6%	0%	15	100%	0%	33	9.1%	0%	31	0%	0%
Mixed Land Use																
Summary for Mixed		39	0%	0%	37	0%	0%	23	100%	0%	42	7.1%	0%	39	0%	0%

[1]Criteria standards for Antimony, Beryllium, Iron, Selenium, and Thallium are 9.0, 0.13, 1.0, 0.26, and 1.4 mg/l respectively

Table 4.3 Percentage of Detections and Exceedances of Oregon State Industrial Stormwater Permit Benchmarks for TSS and Total Oil and Grease[1]

Agency	Station	TSS			Oil &Grease		
		#Samples	%Detect	%Exceed	#Samples	%Detect	%Exceed
Industrial Land Use							
Summary for Industrial		57	100%	28.3%	53	71.7%	7.5%
Transportation Land Use							
Summary for Transportation		23	100%	33.3%	22	90.9%	45.5%
Commercial Land Use							
Summary for Commercial		79	98.7%	21.3%	52	75.0%	3.8%
Residential Land Use							
Summary for Residential		73	97.3%	17.1%	64	67.2%	3.1%
Mixed Land Use							
Summary for Mixed		80	98.8%	26.9%	62	62.9%	4.8%

[1]Benchmarks of 130 mg/l for TSS and 10 mg/l for oil and grease in the Draft 1200-Z NPDES General Permit for storm water system discharges

Table 4-4: Comparison of Conventional Pollutants
Site Median Concentrations with Other Studies for Residential Land Use

Landuse	Station	Other Studies	MEDIAN CONCENTRATIONS												
										Total			Dissolved		
			TSS (mg/l)	BOD5 (mg/l)	COD (mg/l)	Total P (mg/l)	Dissolved P (mg/l)	TKN (mg/l)	NO3+NO2 (mg/l)	Cu (mg/l)	Pb (mg/l)	Zn (mg/l)	Cu (mg/l)	Pb (mg/l)	Zn (mg/l)
Residential	Eugene-R1		52.4	5.5	30.4	0.25	/	0.89	/	0.009	0.018	0.060	0.005	0.0011	0.024
	Gresham-K-4		36.8	3.6	30.9	0.08	0.03	0.55	/	0.007	0.007	0.045	/	/	/
	Portland-R-1*		194.1	7.6	31.4	0.43	/	1.49	/	0.014	0.017	*0.070*	0.004	0.0019	0.012
	Portland-R-2		54.1	7.4	39.9	0.22	/	1.25	/	0.010	0.009	0.086	0.005	0.0009	0.040
	Salem-Redleaf		26.7	2.5	22.1	0.04	/	0.30	/	0.011	/	0.022	/	/	/
	Bell Station		/	/	/	/	/	/	/	/	/	/	/	/	/
	Lake Oswego		28.5	13.4	53.7	0.18	/	1.27	0.44	0.016	0.013	0.136	/	/	/
	Milwaukie		/	/	/	0.37	/	/	/	/	/	/	/	/	/
	Oregon City		12.7	8.1	30.9	0.13	/	1.01	0.42	/	0.004	0.058	/	/	/
	USA-UR2		44.8	5.4	42.6	0.15	/	0.74	0.40	0.014	0.007	0.133	0.006	**	0.071
	Residential - Median		43.2	5.8	33.4	0.15	0.03	0.84	0.37	0.010	0.010	0.069	0.005	0.0013	0.035
		NURP	101	10	73	0.38	0.14	1.9	-	0.033	0.144	0.135	-	-	-
		Santa Clara	66	8	-	0.26	-	1.5	-	0.031	0.037	0.200	-	-	-

NURP: Median values resported for the Nationwide Urban Runoff Program (EPA, 1983)
Santa Clara Valley: Median values for the Nonpoint Source Control Program, 1990

Note: * indicates the station is not used for the landuse assessment
** indicates the station has more than five data, but results are all non-detects or more than sixty percent of results are non-detects
/ indicates the station has none or less than five data for the specific pollutant

Table 4-5: Comparison of Conventional Pollutants Site Median Concentrations with Other Studies for Commercial Land Use

Landuse	Station	Other Studies	TSS (mg/l)	BOD5 (mg/l)	COD (mg/l)	Total P (mg/l)	Dissolved P (mg/l)	TKN (mg/l)	NO3+NO2 (mg/l)	Total Cu (mg/l)	Total Pb (mg/l)	Total Zn (mg/l)	Dissolved Cu (mg/l)	Dissolved Pb (mg/l)	Dissolved Zn (mg/l)
Commercial	Eugene-C1		47.0	9.7	41.5	0.34	/	1.23	/	0.029	0.025	0.108	0.008	0.0019	0.042
	Gresham-M-16		48.3	5.8	37.5	0.06	0.02	0.53	/	0.011	0.014	0.089	/	/	/
	Portland-C-1		56.0	6.1	44.0	0.23	/	1.10	/	0.015	0.037	0.156	0.006	0.0019	0.076
	Portland-C-2		80.9	11.8	57.3	0.36	/	1.35	/	0.034	0.063	0.186	0.009	0.0048	0.087
	Salem-Cottage		69.9	5.3	46.8	0.14	/	0.90	/	0.015	0.013	0.062	/	/	/
	Wilson Rd.		34.5	14.0	62.0	0.14	/	1.61	0.25	/	0.006	0.089	/	/	/
	USA-UC1b		39.4	3.7	29.4	0.19	/	0.58	0.78	0.008	0.013	0.058	0.003	**	0.023
	USA-UC2		34.9	4.6	44.5	0.17	/	0.73	0.26	0.009	0.020	0.074	0.004	**	0.042
	USA-UC3		118.0*	6.5	79.8	0.62	/	1.11	0.31	0.026	0.061	0.222	0.003	**	0.031
	Commercial-Median		55.6	7.4	47.2	0.21	0.02	1.00	0.36	0.022	0.026	0.115	0.006	0.0025	0.051
		NURP	69.0	9.0	57.0	0.20	-	1.20	-	0.029	0.104	0.172	-	-	-
		Santa Clara	66.0	8.0	-	0.26	-	1.50	-	0.031	0.037	0.200	-	-	-

NURP: Median values resported for the Nationwide Urban Runoff Program (EPA, 1983)
Santa Clara Valley: Median values for the Nonpoint Source Control Program, 1990

Note: * indicates the station is not used for the landuse assessment
** indicates the station has more than five data, but results are all non-detects or more than sixty percent of results are non-detects
/ indicates the station has none or less than five data for the specific pollutant

Table 4-6: Comparison of Conventional Pollutants
Site Median Concentrations with Other Studies for Industrial Land Use

Landuse	Station	Other Studies	MEDIAN CONCENTRATIONS												
										Total			Dissolved		
			TSS (mg/l)	BOD5 (mg/l)	COD (mg/l)	Total P (mg/l)	Dissolved P (mg/l)	TKN (mg/l)	NO3+NO2 (mg/l)	Cu (mg/l)	Pb (mg/l)	Zn (mg/l)	Cu (mg/l)	Pb (mg/l)	Zn (mg/l)
Industrial	Eugene-I1		64.1	7.8	49.2	0.40	/	1.00	/	0.021	0.014	0.151	0.006	0.0017	0.053
	Portland-I-1		181.6	53.3	124.0	0.61	/	2.28	/	0.048	0.050	0.558	0.007	0.0019	0.339
	Eugene-I2*		35.9	5.1	31.4	0.28	/	1.00	/	0.013	0.013	0.096	0.008	**	0.040
	Portland-I-2		104.8	25.1	67.4	0.63	/	1.73	/	0.034	0.019	0.253	0.007	0.0018	0.140
	Salem-Edgewater		/	/	/	0.14	/	/	/	/	/	/	/	/	/
	Cow Creek		46.0	10.4	46.9	0.22	/	1.41	0.30	0.013	0.011	0.135	/	/	/
	USA-UI1		/	/	/	/	/	/	/	/	/	/	/	/	/
	Industrial-Median		93.2	18.0	68.8	0.38	/	1.53	0.30	0.032	0.021	0.251	0.007	0.0018	0.131
		Santa Clara	134.0	12.0	-	0.68	-	1.60	-	0.049	0.121	1.324	-	-	-

Santa Clara Valley: Median values for the Nonpoint Source Control Program, 1990

Note: * indicates the station is not used for the landuse assessment
** indicates the station has more than five data, but results are all non-detects or more than sixty percent of results are non-detects
/ indicates the station has none or less than five data for the specific pollutant

Table 4-7: Comparison of Conventional Pollutants
Site Median Concentrations with Other Studies for Transportation Land Use and Open Space Land Use

Landuse	Station	Other Studies	MEDIAN CONCENTRATIONS							Total			Dissolved		
			TSS (mg/l)	BOD5 (mg/l)	COD (mg/l)	Total P (mg/l)	Dissolved P (mg/l)	TKN (mg/l)	NO3+NO2 (mg/l)	Cu (mg/l)	Pb (mg/l)	Zn (mg/l)	Cu (mg/l)	Pb (mg/l)	Zn (mg/l)
Transport	Portland-T-1		107.3	8.2	59	0.27	/	1.19	/	0.027	0.031	0.189	0.007	0.0025	0.077
	ODOT-Eugene		125.2	12.9	/	0.37	/	1.32	/	0.020	0.056	0.156	0.004	**	0.031
	ODOT-Portland		211.2	8.2	/	0.42	/	2.51	/	0.039	0.064	0.254	0.008	0.0023	0.060
	Transport-Median		132.4	8.9	59	0.33	/	1.51	/	0.028	0.043	0.197	0.006	0.002	0.059
		FHWA	142	-	114	0.4	-	1.8	-	0.054	0.4000	0.3290	-	-	-
		Santa Clara	195	-	-	-	-	-	-	0.029	0.0530	0.1420	-	-	-
Open	Portland-OP-1		24.7	3.7	19.1	0.16	/	0.69	/	0.004	0.002	0.012	0.003	/**	0.009
	Open-Median		24.7	3.7	19.1	0.16	/	0.69	/	0.004	0.002	0.012	0.003	/	0.009
		NURP	70	-	40	0.12	-	1.0	-	-	0.030	0.195	-	-	-
		Santa Clara	22	21	-	0.19	-	0.8	-	0.006	0.002	0.007	-	-	-

FHWA: Median values reported for urban highways (Federal Highway Administration, 1990)
NURP: Median values resported for the Nationwide Urban Runoff Program (EPA, 1983)
Santa Clara Valley: Median values for the Nonpoint Source Control Program, 1990

Note: * indicates the station is not used for the landuse assessment
** indicates the station has more than five data, but results are all non-detects or more than sixty percent of results are non-detects
/ indicates the station has none or less than five data for the specific pollutant

Table 4-8: Comparison of Conventional Pollutants Site Median Concentrations with Other Studies for Mixed Land Use

Landuse	Station	Other Studies	MEDIAN CONCENTRATIONS												
										Total			Dissolved		
			TSS (mg/l)	BOD5 (mg/l)	COD (mg/l)	Total P (mg/l)	Dissolved P (mg/l)	TKN (mg/l)	NO3+NO2 (mg/l)	Cu (mg/l)	Pb (mg/l)	Zn (mg/l)	Cu (mg/l)	Pb (mg/l)	Zn (mg/l)
Mixed	Eugene-M1		38.0	7.1	36.8	0.27	/	0.95	/	0.015	0.017	0.081	0.005	**	0.045
	Eugene-M2		22.5	3.1	20.0	0.17	/	0.61	0.31	0.008	0.005	0.030	0.006	**	0.013
	Gresham-E-3		103.1	13.4	72.6	0.07	0.03	1.01	/	0.016	0.023	0.120	/	/	/
	Gresham-l-13		108.0	7.6	48.3	0.08	0.02	0.86	/	0.014	0.026	0.089	/	/	/
	Portland-M-1*		210.2	9.3	60.4	0.79	/	1.70	/	0.018	0.049	0.152	0.004	0.0017	0.037
	Portland-M-2		51.0	4.7	17.8	0.23	/	0.92	/	0.006	0.006	0.030	0.003	0.0013	0.012
	Salem-Commercial		/	/	/	0.22	/	/	/	/	/	/	/	/	/
	USA-Ul2		18.5	/	23.4	0.13	/	0.43	0.50	0.009	0.009	0.048	0.005	**	0.027
	USA-UM1		89.3	/	29.3	0.26	/	0.68	0.71	0.008	0.015	0.050	0.002	**	0.011
	USA-UR1		21.8	/	22.7	0.16	/	0.36	1.29	0.008	0.010	0.046	0.003	**	0.027
		NURP	67.0	8.0	65.0	0.26	-	1.3	-	0.0270	0.1140	0.1540	-	-	-

NURP: Median values resported for the Nationwide Urban Runoff Program (EPA, 1983)

Note: * indicates the station is not used for the landuse assessment
** indicates the station has more than five data, but results are all non-detects or more than sixty percent of results are non-detects
/ indicates the station has none or less than five data for the specific pollutant

Table 5-1: Effect of Sample Size on the Mean's 90% Confidence Interval for TSS

Landuse	Confidence Interval of Mean-Existing Data				Confidence Interval of Mean-Predicted Future					
	Current Sample Size	Upper 90%	Lower 90%	Span of 90%	Pseudo* Sample Size	Upper 90%	Lower 90%	Span of 90%	Percentage Increase in Data Points	Percentage of Decreased in 90% Confidence Interval
Residential	56	48	31	17	77	47	32	15	38%	15%
Commercial	73	69	47	22	97	68	49	19	33%	14%
In-pipe Industrial	25	155	83	72	34	148	87	61	36%	16%
Transportation	23	170	103	67	32	163	107	56	39%	17%

Table 5-2: Effect of Sample Size on the Mean's 90% Confidence Interval for Total Copper

Landuse	Confidence Interval of Mean-Existing Data				Confidence Interval of Mean-Predicted Future					
	Current Sample Size	Upper 90%	Lower 90%	Span of 90%	Pseudo* Sample Size	Upper 90%	Lower 90%	Span 90%	Percentage Increase in Data Points	Percentage of Decreased in 90% Confidence Interval
Residential	51	0.012	0.009	0.0033	69	0.012	0.009	0.0028	35%	15%
Commercial	60	0.027	0.019	0.0082	78	0.026	0.019	0.0072	30%	13%
In-pipe Industrial	21	0.054	0.032	0.0220	27	0.052	0.033	0.0192	29%	13%
Transportation	23	0.035	0.022	0.0136	32	0.034	0.023	0.0114	39%	16%

* Additional data from 3 storm events at each station

Table 6-1. Estimated Costs for Five Station Monitoring Program

Monitoring Task	Estimated Minimum Cost ($)	Estimated Maximum Cost ($)	Units of Measure
Monitoring Plan	12,000	20,000	per 5 stations
Site Selection	3,000	6,000	per 5 stations
Monitoring Equipment (sampler, flow meter, telemetry, equipment enclosure, and software)	25,000	60,000	per 5 stations
Equipment Installation	10,000	30,000	per 5 stations
Training Sampling Crews	4,500	7,000	2-day training
Capital Investment Total	**54,500**	**123,000**	
Sampling Mobilization/Set-up	2,000	3,000	per storm
Storm Event Sampling	1,000	1,200	per storm
Sampling Shut-down	1,500	2,000	per storm
Laboratory Analysis	4,500	7,000	per storm
Data Management	750	1,000	per storm
Sampling Event Total	**9,750**	**14,200**	**per storm**
Data Reporting/Analysis	5,000	10,000	per year
Station Maintenance	3,000	5,000	per year
Equipment Replacement	5,000	9,000	per year
Annual Non-Sampling Total	**13,000**	**24,000**	**per year**
Total Annual Sampling Cost (3 storms/yr)	**44,250**	**66,600**	**per year**